PORTLAND HARBOR RI/FS

~~DRAFT~~ FINAL REMEDIAL INVESTIGATION REPORT

APPENDIX F

BASELINE HUMAN HEALTH RISK ASSESSMENT

~~DRAFT~~ FINAL

This draft document has been provided to EPA at EPA's request to facilitate EPA's comment process on the document in order for LWG to finalize the BHHRA. The comments or changes (including redlines) on this document may not reflect LWG positions or the final resolution of the EPA comments.

~~May 2~~, ~~2011~~2012

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ACG	analytical concentration goal
ADAF	age-dependent adjustment factor
ALM	Adult Lead Methodology
AOPC	Area of Potential Concern
ATSDR	Agency for Toxic Substances and Disease Registry
AWQC	Ambient Water Quality Criteria
BEHP	Bis 2-ethylhexyl phthalate
BERA	baseline ecological risk assessment
BHHRA	baseline human health risk assessment
Cal EPA	California Environmental Protection Agency
CDC	Centers for Disease Control
CDI	chronic daily intake
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
cm	centimeter
cm/hr	centimeters per hour
CNS	central nervous system
COI	contaminant[1] of interest
COPC	contaminant[1] of potential concern
CRITFC	Columbia River Inter-tribal Fish Commission
CSM	conceptual site model
CT	central tendency
DA_{event}	absorbed dose per event
DDD	dichlorodiphenyldichloroethane
DDE	dichlorodiphenyldichloroethylene
DDT	dichlorodiphenyltrichloroethane
delta-HCH	delta-hexachlorocyclohexane
DEQ	Oregon Department of Environmental Quality
DL	detection limit
DQO	data quality objective
E	east
EPA	United States Environmental Protection Agency
EPC	exposure point concentration
EPD	effective predictive domain
FS	feasibility study
g/day	grams per day
GI	gastrointestinal
GSI	Groundwater Solutions, Inc.

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[1] Prior deliverables and some of the tables and figures attached to this document may use the term "Chemical of Interest" or "Chemical of Potential Concern", which as the same meaning as "Contaminant of Interest" or "Contaminant of Potential Concern", respectively, and refers to "contaminants" as defined in 42 USC 9601(33).

HEAST	Health Effects Assessment Summary Table
HHRA	human health risk assessment
HI	hazard index
HQ	hazard quotient
IEUBK	Integrated Exposure Uptake Biokinetic model3
IRAF	Infant Risk Adjustment Factor
IRIS	Integrated Risk Information System
ISA	initial study area
K_p	dermal permeability coefficient
L~~l~~/day	liters per day
LADI	lifetime average daily intake
LOAEL	lowest observed adverse effects level
LWG	Lower Willamette Group
LWR	Lower Willamette River
µg/dL~~l~~	microgram per deciliter
µg/kg	microgram per kilogram
µg/~~l~~L	microgram per liter
MCL	Maximum Contaminant Level
MCPP	2-(4-Chloro-2-methylphenoxy)propanoic acid
mg/kg	milligram per kilogram
ml/day	milliliters per day
ml/hr	milliliters per hour
MRL	method reporting limit
NHANES	National Health and Nutrition Evaluation Survey
NLM	National Library of Medicine
OAR	Oregon Administrative Rules
ODFW	Oregon Department of Fish and Wildlife
ODHS	Oregon Department of Human Services
pg/g	picograms per gram
PAH	polycyclic aromatic hydrocarbon
PBDE	polybrominated diphenyl ether
PCB	polychlorinated biphenyl
PEF	potency equivalency factor
PPRTV	Provisional Peer Reviewed Toxicity Value
PRG	preliminary remediation goal
RBC	risk-based concentration
RfD	reference dose
RG	remediation goal
RI/FS	remedial investigation/feasibility study
RM	river mile
RME	reasonable maximum exposure
RSL	Regional Screening Level
SCRA	site characterization and risk assessment
SF	slope factor
STSC	Superfund Health Risk Technical Support Center

SVOC semi-volatile organic compound
TCDD tetrachlorodibenzo-p-dioxin
TEF toxic equivalency factor
TEQ toxic equivalent
TZW transition zone water
UCL upper confidence limit
~~95% percent UCL/max 95% percent UCL or maximum~~
USDA United States Department of Agriculture
VOC volatile organic compound
W west
WHO World Health Organization
XAD XAD-2 Infiltrex™ 300 system

GLOSSARY

Term	Definition
bioaccumulation	the accumulation of a substance in an organism
bioconcentration factor	the concentration of a chemical in the tissues of an organism divided by the concentration in water
central tendency	a measure of the middle or expected value of a dataset
contaminant of concern	the subset of contaminants[2] of potential concern with exposure concentrations that exceed EPA target risk levels
contaminant of interest	contaminant[2] detected in the Study Area for all exposure media (i.e., surface water, transition zone water, sediment, and tissue)
contaminant of potential concern	the subset of contaminants[2] of interest with maximum detected concentrations that are greater than screening levels
composite sample	an analytical sample created by mixing together two or more individual samples; tissue composite samples are composed of two or more individual organisms, and sediment composite samples are composed of two or more individual sediment grab samples
conceptual site model	a description of the links and relationships between chemical sources, routes of release or transport, exposure pathways, and the human receptors at a site
congener	a specific chemical within a group of structurally related chemicals (e.g., PCB congeners)
human health risk assessment	a process to evaluate the likelihood that adverse effects to human health might occur or are occurring as a result of exposure to one or more contaminants
dose	the quantity of a contaminant taken in or absorbed at any one time, expressed on a body weight-specific basis; units are generally expressed as mg/kg bw/day
empirical data	data quantified in a laboratory
exposure assessment	the part of a risk assessment that characterizes the chemical exposure of a receptor

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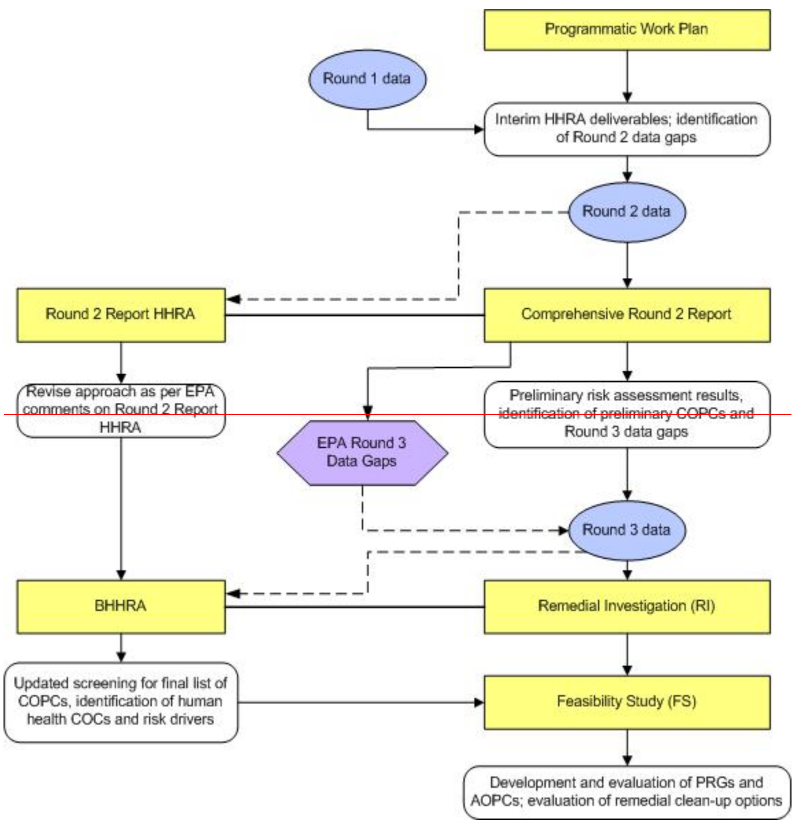
Term	Definition
exposure pathway	physical route by which a contaminant moves from a source to a human receptor
exposure point	the location or circumstances in which a human receptor is assumed to contact a contaminant
exposure point concentration	the value that represents the estimated concentration of a contaminant at the exposure point
exposure area	size of the area through which a receptor might come in contact with a contaminant as determined by human uses
hazard quotient	the quotient of the exposure level of a chemical divided by the toxicity value based on noncarcinogenic effects (i.e., reference dose)
predicted data	data not quantified in a laboratory but estimated using a model
reasonable maximum exposure	the maximum exposure reasonably expected to occur in a population
receptor	The exposed individual relative to the exposure pathway considered
risk	the likelihood that a specific human receptor experiences a particular adverse effect from exposure to contaminants from a hazardous waste site; the severity of risk increases if the severity of the adverse effect increases or if the chance of the adverse effect occurring increases. Specifically for carcinogenic effects, risk is estimated as the incremental probability of an individual developing cancer over a lifetime as a result of exposure to a potential carcinogen. Specifically for noncarcinogenic (systemic) effects, risk is not expressed as a probability but rather is evaluated by comparing an exposure level over a period of time to a reference dose derived for a similar exposure period.
risk characterization	a part of the risk assessment process in which exposure and effects data are integrated in order to evaluate the likelihood of associated adverse effects
slope factor	toxicity value for evaluating the probability of an individual developing cancer from exposure to contaminant levels over a lifetime
Study Area	the portion of the Lower Willamette River that extends from River Mile 1.9 to River Mile 11.8
toxic equivalency factor	numerical values developed by the World Health Organization that quantify the toxicity of dioxin, furan, and dioxin-like PCB congeners relative to 2,3,7,8-tetrachlorodibenzodioxin

Term	Definition
transition zone water	Pore water associated with the upper layer of the sediment column; may contain both groundwater and surface water
uncertainty	a component of risk resulting from imperfect knowledge of the degree of hazard or of its spatial and temporal distribution
upper confidence limit on the mean	a high-end statistical measure of central tendency
variability	a component of risk resulting from true heterogeneity in exposure variables or responses, such as dose-response differences within a population or differences in contaminant levels in the environment

~~EXECUTIVE SUMMARY~~

~~The baseline human health risk assessment (BHHRA) was conducted as part of the Remedial Investigation Report (RI Report) for the Portland Harbor Superfund Site (Site). The BHHRA is an analysis of potential adverse health effects (current or future) caused by hazardous substance releases from a site in the absence of any actions to control or mitigate these releases. The results of the BHHRA are used to develop remedial action objectives and to assist in risk management decisions for the Site. Figure ES-1 presents an overview of how the development and production of the BHHRA fits in with the overall Remedial Investigation/Feasibility Study (RI/FS) process for the Portland Harbor Superfund Site.~~

~~Figure ES-1 Portland Harbor RI/FS Process and BHHRA~~



~~The general objective of the BHHRA is to assess the potential risks to human health from exposure to site-related chemicals present in or entering into environmental~~

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~~media (i.e., water or sediment) or bioaccumulating in the food chain, to assist in determining the need for remedial action, to assist in providing a basis for determining concentrations of chemicals that can remain in place and still be protective of public health, and to assist in providing a basis for comparing the effectiveness of various remedial alternatives. Specifically, this included evaluating whether exposure to chemicals in sediment, surface water, groundwater seeps, or biota may result in unacceptable risks to human health.~~

~~The BHHRA followed the approach that was documented in the Programmatic Work Plan (Integral et al. 2004) and subsequent interim deliverables. It also reflects numerous discussions, directives, and agreements on risk assessment techniques for the Site with or from the United States Environmental Protection Agency (EPA), Oregon Department of Environmental Quality (DEQ), Oregon Department of Human Services (ODHS), and Native American Tribes. To minimize the chances of underestimating risks, the BHHRA incorporated conservative (i.e. health-protective) assumptions into the identification of exposure scenarios, the estimates of exposure, and the use of toxicity values.~~

~~Industrial use of Portland Harbor and adjacent areas of the Lower Willamette River (LWR) has been extensive. Portland Harbor generally refers to a heavily industrialized reach of the LWR between river mile (RM) 0 and RM 11.8, the extent of the navigation channel. The approximate 10-mile portion of Portland Harbor from RM 1.9 to 11.8 is referred to as the Study Area, which is the focus of the BHHRA. Potential human uses of Portland Harbor were considered in identifying the exposure scenarios and exposure media for evaluation in the BHHRA.~~

~~ES.1 BHHRA DATASET~~

~~The BHHRA dataset includes those data used for direct human health exposure pathways that were quantitatively evaluated in the risk characterization sections of the document: surface sediment (0 to 30.5 centimeter (cm) in depth), surface water, groundwater seep water, clam and crayfish tissue, and fish tissue. Other matrices included in the site characterization and risk assessment (SCRA) dataset (e.g., subsurface sediment) were not evaluated in the BHHRA because they were not relevant to the exposure scenarios evaluated. Although the BHHRA focused on the Study Area, data from outside the Study Area, from downstream to RM 1.0, including Multnomah Channel, and upstream to RM 12.2, were also used to assess risk, per an agreement with EPA. The following summarizes the data used by medium in the BHHRA dataset by medium:~~

- ~~Beach sediment: Composite beach sediment samples that were collected from designated human use areas within the Study Area were included in the BHHRA dataset.~~

- ~~In-water sediment: In-water sediment (i.e., not beach sediment) samples that were collected from the top 30.5 cm in depth between the bank and the navigation channel were included in the BHHRA da~~dataset~~.~~
- ~~Surface water: All Round 2 and Round 3 surface water data collected within the Study Area and in Multnomah Channel were included in the BHHRA dataset.~~ .
- ~~Groundwater seep: Data from Outfall 22B, which discharges in a potential human use area, were included in the BHHRA dataset.~~ . ~~Samples collected from this outfall as part of a stormwater sampling event were excluded from the BHHRA groundwater seep dataset.~~
- ~~Fish tissue: Composite samples, both whole body and fillet with skin (fillet without skin samples were analyzed for mercury only), of target resident fish species (smallmouth bass, brown bullhead, black crappie, and common carp) were included in the BHHRA dataset.~~ . ~~Composite samples of adult Chinook salmon (whole body, fillet with skin, and fillet without skin), adult lamprey (whole body only), and sturgeon (fillet without skin only) were also included in the BHHRA dataset.~~
- ~~Shellfish tissue: Field-collected composite samples of crayfish and clam tissue (depurated and undepurated) were included in the BHHRA dataset.~~ .

~~ES.2 BHHRA EXPOSURE SCENARIOS~~

~~The risk characterization in the BHHRA evaluated the following exposure scenarios, as provided in the approved Programmatic Work Plan and subsequent agreements with or directives from the EPA related to the BHHRA approach:~~

	~~**Beach Sediment:** Ingestion and dermal absorption~~	~~**In-water Sediment:** Ingestion and dermal absorption~~	~~**Surface Water:** Ingestion and dermal Absorption~~	~~**Groundwater Seeps:** Ingestion and dermal absorption~~	~~**Fish/ Shellfish:** Ingestion~~	~~**Infant Consumption of Human Milk**~~
~~Workers~~	●	●	-	-	-	●
~~Transients~~	●	-	●	●	-	
~~Beach Users~~	●	-	●	-	-	
~~Fishers~~	●	●	-	-	●	●
~~Divers~~	–	●	●	-	-	●
~~Domestic Users~~	-	-	●	-	-	

- ~~Dockside worker—direct exposure to (i.e., ingestion of and dermal contact with) beach sediment, infant ingestion of human breast milk.~~
- ~~In-water worker—direct exposure to in-water sediment, infant ingestion of human breast milk.~~
- ~~Transient—direct exposure to beach sediment, surface water (for bathing and drinking water scenarios), and groundwater seeps.~~
- ~~Adult and child recreational beach user—direct exposure to beach sediment and surface water (for swimming scenarios).~~
- ~~Tribal fisher—direct exposure to beach sediment or in-water sediment, fish consumption, and infant ingestion of human breast milk.~~
- ~~Fisher—direct exposure to beach sediment or in-water sediment, fish consumption, shellfish consumption, and infant ingestion of human breast milk.~~
- ~~Diver—direct exposure to in-water sediment and surface water, infant ingestion of human breast milk.~~
- ~~Domestic water user—~~hypothetical ~~direct exposure to untreated surface water hypothetically used as a drinking water source in the future.~~

~~Exposures to beach sediment were assessed per beach, and exposures to groundwater seeps were assessed per seep. Exposures to in-water sediment, surface water, and fish and shellfish tissue were assessed on both localized and Study Area-wide scales. Details of each exposure scenario and associated exposure parameters are provided in Section 3 of this BHHRA.~~

~~Of these scenarios, the following were evaluated at the direction of EPA: clam tissue ingestion, fish ingestion for single-species diets, exposure to in-water sediment and surface water by commercial divers, and hypothetical exposure to untreated surface water by a domestic user. Even though surface water in the LWR within Portland Harbor is not currently used as a domestic water source, under OAR 340-041-0340 Table 340A, domestic water supply is a designated beneficial use of the Willamette River, with adequate pretreatment. Divers and clam consumption by fishers were not included in the original Programmatic Work Plan but were included in the BHHRA as directed by EPA. Asian clams (*Corbicula* sp.) are the only clam species that were found in the Study Area during sampling events and, in addition to crayfish, were evaluated for shellfish consumption in the BHHRA. Although harvest and possession of Asian clams is illegal in the State of Oregon, conversations with transients indicated shellfish (both crayfish and clams) are eaten by them (Wagner 2004). In addition, crayfish are commercially harvested in the Willamette River, although the extent of this harvest within the Portland Harbor Superfund Site is not known.~~

~~ES.3 BHHRA EXPOSURE ASSESSMENT~~

~~The exposure assessment incorporated the reasonable maximum exposure (RME) approach described by EPA (1989). . The RME is intended to be a conservative exposure level that is still within the range of possible exposures. . Consistent with EPA (1989), the exposure assessment also used evaluated a central tendency (CT) values, which is intended to represent average exposures, for certain exposure assumptions. . For some exposure scenarios, such as fish consumption, exposure assumptions were directed by EPA. . Exposure point concentrations (EPCs) were calculated for each exposure area for as the 95% percent upper confidence limit on the arithmetic mean (95% percent UCL) for the RME evaluations and the arithmetic mean for the CTE evaluations for each exposure area. . In some exposure areas,certain instances the maximum concentration was used as the EPC instead of the 95% percent UCL. . These instances included those exposure areas where there are an insufficient number of samples to calculate a 95 percent UCL, and when the calculated UCL was greater than the maximum detected concentration. . Therefore, the EPCs are referred to as the 95% UCL/max and mean throughout the BHHRA.~~

~~EPCs for sediment, surface water, and tissue were also calculated for individual exposure areas and on a Study Area-wide basis. . The spatial scale of the individual exposure areas and the resulting data included in the calculation of those EPCs were predetermined through discussions with EPA based on assumptions about potential human uses as well as the species' home ranges in the case of tissue EPCs. . Exposure areas were designated throughout the Study Area based on the predetermined spatial scales. .~~

~~Assumptions about each population evaluated in the BHHRA were used to select exposure parameters to calculate the pathway-specific chemical intakes. . Site-specific values are not available for all populations and pathways. . Therefore, default values were used where site-specific values are not available. . Where default values are not available, best professional judgment based on knowledge of human uses of the Study Area or requirements from EPA were used. . Uncertainties that are inherent in exposure assessment are attributed to both variability in the population assessed and also the degree of knowledge associated with exposure assumptions. These uncertainties associated with the exposure assessment impact the risk estimates (EPA 1989).~~

~~ES.4 BHHRA TOXICITY ASSESSMENT~~

~~Toxicity values provide a quantitative estimate of the potential for adverse effects resulting from exposure to a chemical. . Cancer and noncancer toxicity values are used in human health risk assessments to quantify the likelihood of adverse effects occurring at different levels of exposure to a chemical. . Toxicity values are often based on the results of animal studies, and the extrapolation of toxicological data from animal studies to humans can be one of the largest sources of uncertainty in a~~

~~risk assessment.~~ ~~Modifying factors, which typically range from two to three orders of magnitude (100 to 1,000 times), are often used by EPA in deriving toxicity values for human health given the level of confidence in the toxicological data, the intra-species differences (i.e., animal to human), and the inter-species differences to account for sensitive human subpopulations.~~

~~Some toxicity values are based on exposure to chemical mixtures and not to individual chemicals.~~ ~~This is because these chemicals are commonly present as mixtures in the environment, and the individual components of the mixtures have similar modes of toxicity (such as dioxins).~~ ~~The chemicals that were evaluated in the BHHRA for toxicity as mixtures include: chlordanes, dichlorodiphenyldichloroethane (DDD), dichlorodiphenyldichloroethylene (DDE), and dichlorodiphenyltrichloroethane (DDT);), endosulfan; , polychlorinated biphenyls (PCBs); and dioxins and furans.~~

~~ES.5 BHHRA RISK CHARACTERIZATION~~

~~Consistent with DEQ (DEQ 2000a) and EPA guidance (EPA 1989), noncarcinogenic and carcinogenic effects were evaluated separately in the BHHRA.~~ ~~To characterize potential noncarcinogenic effects, comparisons were made between projected intakes of substances and toxicity values.~~ ~~To characterize potential carcinogenic effects, projected intakes and chemical-specific, dose-response data were used to estimate the probability that an individual will develop cancer over a lifetime.~~

~~Hazard quotients (HQs) were calculated for noncarcinogenic contaminants of potential concern (COPCs) to estimate the potential for noncarcinogenic effects.~~ ~~The HQs were then summed to yield cumulative hazard indices (HIs) for each exposure area and for the entire Study Area.~~ ~~Estimated HIs were compared to a target HI of 1.~~ ~~For exposure areas exceeding a cumulative HI of 1, endpoint-specific HIs were then calculated and compared to a target HI of 1, below which remedial action at a Superfund site is generally not warranted (EPA 1991a)adverse health effects are not expected.~~

~~Table ES-1 shows the ranges of cancer risks and HIs for each receptor and medium.~~ ~~The exposure pathway with the highest range of HI estimates is consumption of fish tissue.~~ ~~For the most part, exposure scenarios other than fish and shellfish consumption did not exceed a target HI of 1.~~ ~~The ranges of HI estimates are due to the evaluation of different exposure areas, RME and CT scenarios for sediment and water, and multiple ingestion rates and diets for tissue consumption.~~ ~~For example, the range of HI estimates for tissue encompass results for both adult and child consumers, results from three different ingestion rates for each receptor, and results from five different diet compositions.~~

~~Potential cancer risks were calculated for carcinogenic COPCs.~~ ~~This calculated risk is expressed as the probability of an individual developing cancer over a lifetime as a~~

~~result of exposure to the potential carcinogen, and is a health protective estimate of the incremental probability of excess individual lifetime cancer risk.~~ . ~~Estimated total cancer risks (summed across all chemicals) were compared to a 1 x~~ x ~~10^{-4} to 1 x~~ x ~~10^{-6} risk range, which is the "target range" within which the EPA strives to manage risk as a part of the Superfund program (EPA 1991a).~~ . ~~The DEQ target risk levels are 1 x~~ x ~~10^{-6} for individual carcinogens and 1 x~~ x ~~10^{-5} for total cancer risks.~~

~~As shown below in Table ES-1, the exposure pathway with the highest range of cancer risk estimates is consumption of fish tissue.~~ . ~~For the most part, exposure scenarios other than fish and shellfish consumption were within or below the target risk range of 1 x~~ x ~~10^{-4} to 1 x~~ x ~~10^{-6}.~~ . ~~The ranges of cancer risk estimates are due to the evaluation of different exposure areas, RME and CT scenarios for sediment and water, and multiple ingestion rates and diets for tissue consumption. Round 1 fillet tissue samples were not analyzed for PCB, dioxin, or furan congeners.~~ . ~~Therefore, the risks from consumption of black crappie and brown bullhead fillet tissue, which were only analyzed in Round 1, likely underestimate the actual risks.~~ . ~~However, a range of risks was calculated for fish consumption scenarios, which included samples that were analyzed for congeners, so the lack of analysis of chemicals in certain samples should not impact the overall conclusions of this BHHRA.~~

Table ES-1. Ranges of Estimated Cumulative Excess Lifetime Cancer Risks and Hazard Indices for Portland Harbor Human Health Scenarios

		RME Scenarios				CT Scenarios			
		Estimated Cancer Risk		Cumulative Hazard Index		Estimated Cancer Risk		Cumulative Hazard Index	
Exposure Scenario	**Receptor**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**
Direct Exposure to Beach Sediment	Dockside Worker	5.E-07	**9.E-05**	2.E-03	7.E-02	4.E-08	**6.E-06**	5.E-04	1.E-02
	Transient	1.E-07	6.E-07	4.E-02	1.E-01	8.E-09	4.E-08	6.E-03	1.E-02
	Adult Recreational Beach User	5.E-07	**4.E-06**	8.E-03	3.E-02	2.E-08	2.E-07	2.E-03	6.E-03
	Child Recreational Beach User	**2.E-06**	**4.E-05**	8.E-02	4.E-01	2.E-07	**2.E-06**	1.E-02	5.E-02
	Combined Adult/Child Recreational Beach User	**2.E-06**	**5.E-05**	NA	NA	2.E-07	**2.E-06**	NA	NA
	Tribal Fisher	**2.E-06**	**2.E-05**	2.E-02	8.E-02	1.E-07	**2.E-06**	3.E-03	3.E-02
	Low-Frequency Fisher	4.E-07	**4.E-06**	7.E-03	3.E-02	1.E-08	1.E-07	8.E-04	3.E-02
	High-Frequency Fisher	5.E-07	**6.E-06**	1.E-02	5.E-02	2.E-08	3.E-07	2.E-03	3.E-02
	Breastfeeding Infant	7.E-09	1.E-06	1.E-02	1.E+00	5.E-10	9.E-08	2.E-03	2.E-01
Direct Exposure to Groundwater Seep	Transient	3.E-09	3.E-09	6.E-03	6.E-03	4.E-10	4.E-10	1.E-03	1.E-03
Direct Exposure to In-water Sediment	Diver in Dry Suit	3.E-08	**1.E-05**	2.E-04	2.E-01	NA	NA	NA	NA
	Diver in Wet Suit	9.E-08	**3.E-05**	7.E-04	6.E-01	3.E-09	6.E-07	6.E-05	1.E-02
	In-water Worker	7.E-08	**2.E-05**	1.E-03	1.E+00	5.E-09	4.E-07	2.E-04	6.E-02
	Tribal Fisher	1.E-06	**3.E-04**	3.E-03	**3.E+00**	6.E-08	**6.E-06**	3.E-04	9.E-02
	Low-Frequency Fisher	2.E-07	**6.E-05**	1.E-03	1.E+00	5.E-09	4.E-07	9.E-05	2.E-02
	High-Frequency Fisher	3.E-07	**8.E-05**	2.E-03	**2.E+00**	9.E-09	9.E-07	2.E-04	4.E-02
	Breastfeeding Infant	5.E-10	**3.E-04**	7.E-04	**5.E+00**	4.E-11	**3.E-06**	3.E-04	1.E-01
Direct Exposure to Surface Water	Diver in Dry Suit	1.E-08	**2.E-06**	6.E-05	2.E-03	NA	NA	NA	NA
	Diver in Wet Suit	1.E-08	**1.E-05**	8.E-05	6.E-03	8.E-10	5.E-07	1.E-05	7.E-04
	Transient	6.E-07	7.E-07	4.E-02	4.E-01	7.E-08	1.E-07	1.E-02	8.E-02
	Adult Recreational Beach User	2.E-08	2.E-08	1.E-04	1.E-04	2.E-09	2.E-09	3.E-05	3.E-05
	Child Recreational Beach User	4.E-08	5.E-08	1.E-03	1.E-03	8.E-09	9.E-09	2.E-04	2.E-04
	Combined Adult/Child Recreational Beach User	6.E-08	7.E-08	NA	NA	9.E-09	1.E-08	NA	NA
Surface Water as Hypothetical Drinking Water Source	Domestic User, Adult	**6.E-06**	**3.E-04**	3.E-02	7.E-01	1.E-06	**3.E-05**	2.E-02	3.E-01
	Domestic User, Child	**4.E-06**	**7.E-04**	1.E-01	**2.E+00**	**2.E-06**	**2.E-04**	5.E-02	8.E-01
	Domestic User, Combined Adult/Child	**9.E-06**	**9.E-04**	NA	NA	**3.E-06**	**2.E-04**	NA	NA

Table ES-1 (continued). Ranges of Estimated Cumulative Excess Lifetime Cancer Risks and Hazard Indices for Portland Harbor Human Health Scenarios

		RME Scenarios				CT Scenarios			
		Estimated Cancer Risk		Cumulative Hazard Index		Estimated Cancer Risk		Cumulative Hazard Index	
Exposure Scenario	**Receptor**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**
Tribal Fish Ingestion	Tribal Adult Consumer	2.E-02	2.E-02	4.E+02	4.E+02	5.E-03	5.E-03	9.E+01	9.E+01
Multi-Species Diet	Tribal Child Consumer	3.E-03	3.E-03	8.E+02	8.E+02	8.E-04	8.E-04	2.E+02	2.E+02
Whole Body Tissue	Combined Tribal Adult/Child Consumer	2.E-02	2.E-02	NA	NA	5.E-03	5.E-03	NA	NA
Approximate number of meals per month: 23	Breastfeeding Infant	2.E-02	2.E-02	9.E+03	9.E+03	5.E-03	5.E-03	2.E+03	2.E+03
Tribal Fish Ingestion	Tribal Adult Consumer	1.E-02	1.E-02	3.E+02	3.E+02	2.E-03	2.E-03	5.E+01	5.E+01
Multi-Species Diet	Tribal Child Consumer	2.E-03	2.E-03	6.E+02	6.E+02	4.E-04	4.E-04	1.E+02	1.E+02
Fillet Tissue	Combined Tribal Adult/Child Consumer	1.E-02	1.E-02	NA	NA	3.E-03	3.E-03	NA	NA
Approximate number of meals per month: 23	Breastfeeding Infant	1.E-02	1.E-02	8.E+03	8.E+03	2.E-03	2.E-03	1.E+03	1.E+03
Fish Ingestion	Adult Consumer	7.E-05	6.E-02	2.E+00	3.E+03	7.E-05	2.E-02	2.E+00	1.E+03
Single-Species Diet	Child Consumer	3.E-05	2.E-02	4.E+00	5.E+03	3.E-05	8.E-03	4.E+00	2.E+03
Whole Body Tissue	Combined Adult/Child Consumer	9.E-05	7.E-02	NA	NA	8.E-05	2.E-02	NA	NA
Approximate number of meals per month: 2 - 19	Breastfeeding Infant	8.E-05	7.E-02	3.E+01	6.E+04	7.E-05	2.E-02	3.E+01	2.E+04
Fish Ingestion	Adult Consumer	7.E-06	4.E-02	5.E-01	2.E+03	7.E-06	1.E-02	5.E-01	7.E+02
Single-Species Diet	Child Consumer	3.E-06	1.E-02	1.E+00	4.E+03	3.E-06	5.E-03	9.E-01	1.E+03
Fillet Tissue	Combined Adult/Child Consumer	9.E-06	4.E-02	NA	NA	8.E-06	2.E-02	NA	NA
Approximate number of meals per month: 2 - 19	Breastfeeding Infant	6.E-06	2.E-02	7.E+00	5.E+04	6.E-06	2.E-02	7.E+00	2.E+03
Fish Ingestion	Adult Consumer	1.E-03	1.E-02	8.E+01	6.E+02	4.E-04	3.E-03	2.E+01	1.E+02
Multi-Species Diet	Child Consumer	6.E-04	5.E-03	1.E+02	1.E+03	1.E-04	1.E-03	3.E+01	3.E+02
Whole Body Tissue	Combined Adult/Child Consumer	2.E-03	1.E-02	NA	NA	4.E-04	4.E-03	NA	NA
Approximate number of meals per month: 2 - 19	Breastfeeding Infant	2.E-03	1.E-02	2.E+03	1.E+04	4.E-04	4.E-03	3.E+02	3.E+03
Fish Ingestion	Adult Consumer	1.E-03	9.E-03	6.E+01	5.E+02	2.E-04	1.E-03	9.E+00	7.E+01
Multi-Species Diet	Child Consumer	4.E-04	4.E-03	1.E+02	1.E+03	6.E-05	6.E-04	2.E+01	1.E+02
Fillet Tissue	Combined Adult/Child Consumer	1.E-03	1.E-02	NA	NA	2.E-04	2.E-03	NA	NA
Approximate number of meals per month: 2 - 19	Breastfeeding Infant	1.E-03	1.E-02	2.E+03	1.E+04	2.E-04	2.E-03	2.E+02	2.E+03
Shellfish Ingestion (clam or crayfish)	Adult Consumer	9.E-07	7.E-04	7.E-02	4.E+01	9.E-07	7.E-04	6.E-02	4.E+01
Approximate number of meals per month: 0.4 - 2.5	Breastfeeding Infant	1.E-10	7.E-04	5.E-04	8.E+02	1.E-10	7.E-04	4.E-04	8.E+02

Notes:

Values presented are for exposure areas assessed in the BHHRA that lie within the Study Area.

Bolded cells exceed the EPA target cancer risk level of 1 x 10^{-6} or the target hazard index of 1.

Highlighted cells exceed the EPA target cancer risk level of 1 x 10^{-4} or the target hazard index of 1.

For tissue ingestion, the RME scenario represents the 95 percent upper confidence limit/maximum exposure point concentration. The CT scenario represents the mean exposure point concentration.

The exposure medium shown for the breastfeeding infant represents the exposure medium for the adult.

Ranges for tissue ingestion include all consumption rates.

NA = Not applicable because a CT scenario was not evaluated or because hazard indices were not calculated for the combined adult/child scenario.

Hazard indices presented are the ranges for cumulative hazard indices per exposure area and exposure scenario. Endpoint-specific hazard indices were calculated for cumulative hazard indices greater than 1.

For tissue ingestion, number of meals per month is calculated based on an 8 ounce serving for adults a 3.4 ounce serving for children.

For both cancer risks and noncancer hazards, the maximum estimates are for fish consumption and represent the highest consumption rate, the 95% UCL or maximum tissue concentrations, and localized exposure areas. . The following summarizes the assumptions associated with the highest risk estimates:

- **Fish ingestion rate.** . The highest ingestion rates used in this BHHRA for adult tribal fishers and adult fishers are 175 g/day (CRITFC 1994) and 142 g/day (EPA 2002b), respectively. . These are equivalent to 23 and 19 meals per month, respectively, based on an 8-ounce serving size, every month of the year exclusively of fish caught within the Study Area.
- **Exposure duration.** . Fish consumption is assumed to occur at that same rate every month of every year for 30 years for adult fishers and 70 years for tribal fishers. .
- **Whole body tissue.** . WOnly whole body tissue (i.e., the entire fish) is consumed. .
- **Single species.** . For non-tribal fishers, only one species (i.e., common carp) is consumed. .
- **Source of fish.** . 100 percent of the fish consumed is caught/harvested from the same location.

In addition to the uncertainty associated with the exposure assumptions listed above, there are uncertainties associated with the cooking and preparation methods for fish consumption and background contributions to the Study Area. Possible the possible effects of cooking methods, which can reduce concentrations of lipophilic chemicals in fish tissue, were not considered. . PCB concentrations have been shown to be reduced with various cooking methods though due to the variability in the measured rates of reduction there is uncertainty in assigning a rate of reduction of PCBs associated with cooking and preparation methods. . Assumptions made during this BHHRA introduce uncertainty to the actual risks that may exist within the Study Area. . The contribution of background sources is another important consideration. . On a regional scale, fish consumption results in risk estimates exceeding cumulative risks of 10^{-4} or HIs of 1 based on fish tissue data collected from the Willamette and Columbia Rivers outside of the Study Area (EVS 2000, EPA 2002c). However, concentrations are higher at the Site than in the regional tissue.

Chemicals were identified as contaminants potentially posing unacceptable risks[3] if they resulted in a cancer risk greater than the EPA point of departure of 1 x x 10^{-6} or a HQ greater than 1 under any of the exposure scenarios for any of the exposure point concentrations evaluated in the BHHRA, regardless of the uncertainties. . There were 28 chemicals identified as contaminants potentially posing unacceptable risks for the

[3] Prior deliverables and some of the tables and figures attached to this document may use the term "Chemicals posing potentially unacceptable risks," which has the same meaning as "Contaminant posing potentially unacceptable risks" and refers to "contaminants" as defined in 42 USC 9601(33).

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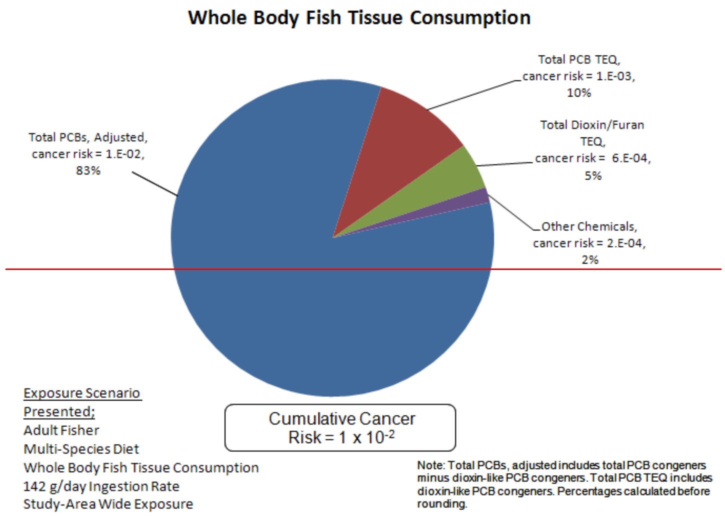
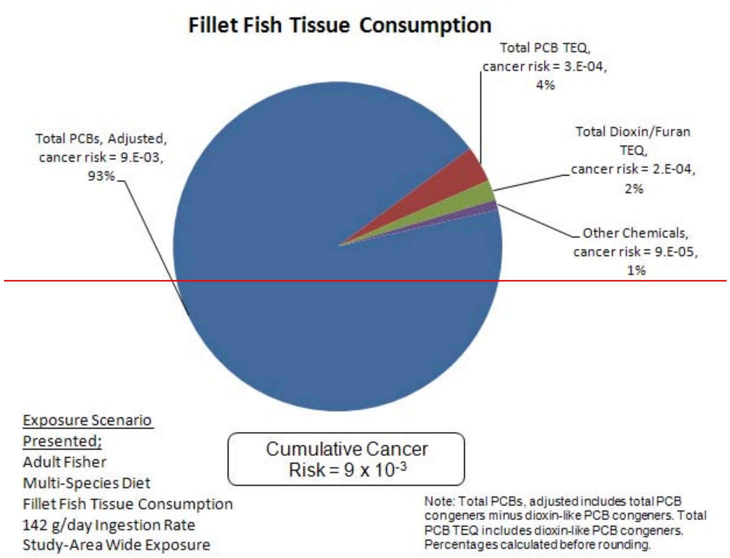
~~exposure scenarios listed above.~~ . ~~Only a subset of these contaminants were associated with cancer risks exceeding 1 x~~ x ~~10^{-4} or HQs exceeding 1, and an even smaller number of contaminants contributed to most of the relative percentage of total risk.~~ . ~~Of the 33 contaminants identified as potentially posing unacceptable risks, four of the chemicals (alpha-, beta-, and gamma-hexachlorocyclohexane and heptachlor) were identified on the basis of N-qualified data only.~~ . ~~The use of an "N" qualifier indicates that the identity of the analyte is not definitive.~~ . ~~These four chemicals are not recommended for further evaluation of potential risks to human health.~~ . ~~The remaining 29 contaminants identified as potentially posing unacceptable risks to human health are evaluated further in the Human Health Risk Management Recommendations.~~

~~As shown in Figure ES-1, PCBs contribute the majority of the total cancer risk for the fish tissue consumption pathway (both whole body and fillet tissue) on a Study Area-wide exposure area basis, and are the primary contributor to risk under this exposure scenario.~~ . ~~Dioxins and furans are the secondary contributor to risk. PCBs contribute approximately 93 percent of the cumulative cancer risk, and dioxins/furans contribute approximately 5 percent of the cumulative cancer risk for Study Area-wide whole body fish tissue consumption.~~ . ~~For fillet tissue consumption, PCBs contribute approximately 97 percent of the cumulative cancer risk, and dioxins/furans contribute approximately 2 percent for Study Area-wide exposure. The remaining COPCs for Study Area-wide fish consumption account for less than 2 percent of the cumulative cancer risk.~~ . ~~PCBs and dioxins/furans also resulted in the highest HQs for Study Area-wide fish tissue consumption.~~

~~**Figure ES-1. Relative Contribution of Individual Analytes to Cumulative Study Area-Wide Risk For The Non-Tribal Adult Fish Consumption Scenario, Whole Body and Fillet Tissue**~~



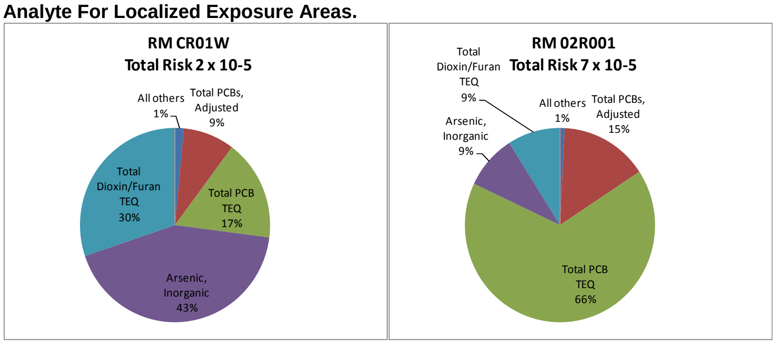


~~While tissue concentrations and risks are higher in Portland Harbor, in regional studies of fish tissue data from the Willamette and Columbia Rivers outside of the~~

~~Study Area (EVS 2000, EPA 2002c) both PCBs and dioxins/furans also resulted in cancer risks greater than 1 x~~ x ~~10^{-4} and/or HQs greater than 1 for fish consumption using exposure assumptions similar to those in the BHHRA.~~

~~In some cases in the Portland Harbor, contaminants contributing most to cumulative risks differ between localized exposure areas.~~ ~~For example, Figure ES-2 shows the relative contribution of contaminants to cumulative cancer risks from ingestion of crayfish tissue by an adult fisher at two different localized exposure areas.~~ ~~In the pie chart on the left, which shows relative risks from consumption of crayfish at sampling station CR01W, arsenic is the primary contributor to cancer risk (42%~~ percent ~~of total risk), followed by total dioxin/furan TEQ (30%~~ percent ~~of total risk). The pie chart on the right shows relative risks from consumption of crayfish at sampling station RM 02R001, where ingestion of PCBs in shellfish tissue contributes to approximately 81%~~ percent ~~of total cancer risks (total adjusted PCBs plus total PCB TEQ), followed by an almost equal contribution from arsenic and total dioxin/furan TEQ (approximate 9%~~ percent ~~contribution to total risks by each contaminant)~~

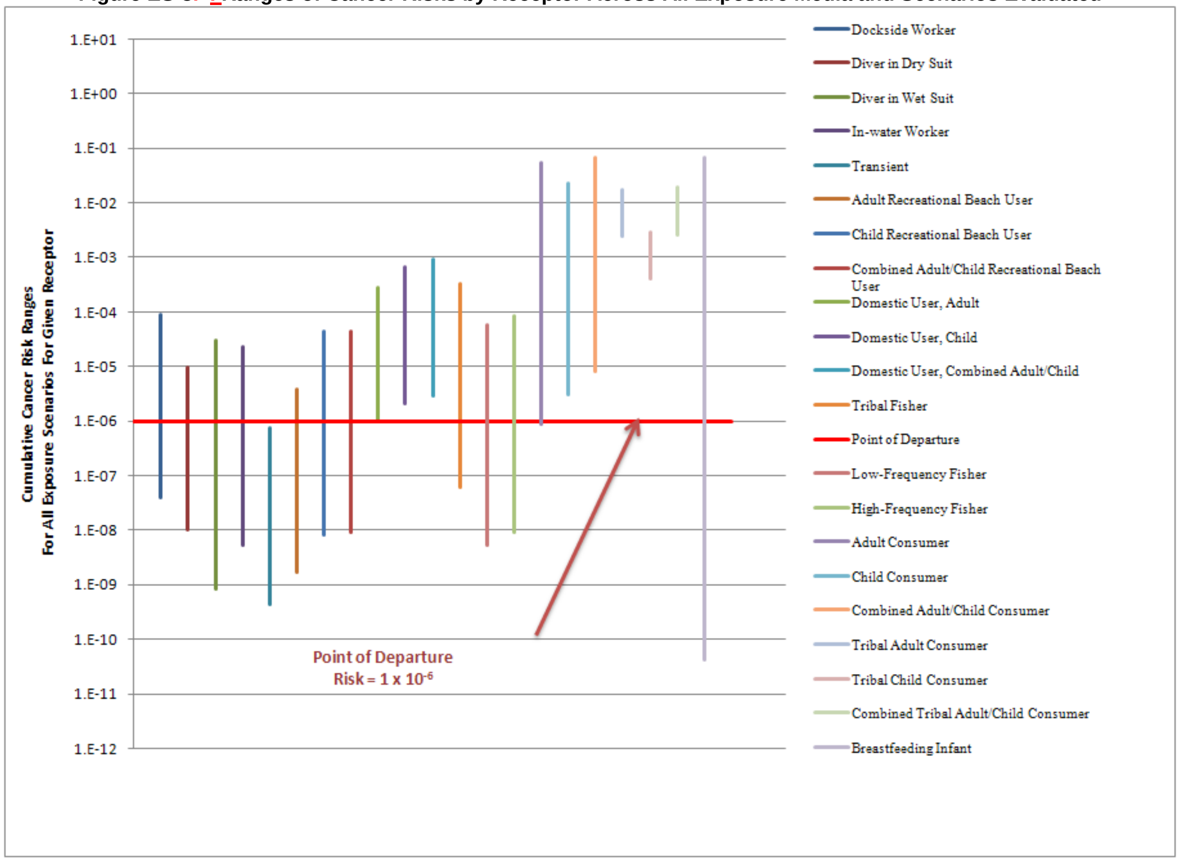
Figure ES-2~~.~~. Example of Differing Relative Contributions to Cumulative Risk by Analyte For Localized Exposure Areas.



Figures show relative risks from adult fisher consumption of crayfish tissue at the 95~~%~~ percent UCL/Max Exposure Point Concentrations

~~A detailed breakdown of risks by exposure scenario, contaminant, and exposure area is provided in the figures and tables in Section 5 of this BHHRA.~~ ~~In addition, Figure ES-3 and ES-4 provide a visual representation of the ranges of cancer risks (ES-3) and noncancer hazards (ES-4) by receptor. Fish tissue consumers have the highest estimated cancer and noncancer risks.~~

Figure ES-3~~.~~. Ranges of Cancer Risks by Receptor Across All Exposure Media and Scenarios Evaluated



~~This draft document has been provided to EPA at EPA's request to facilitate EPA's comment process on the document in order for LWG to finalize the BHHRA. The comments or changes (including redlines) on this document may not reflect LWG positions or the final resolution of the EPA comments.~~

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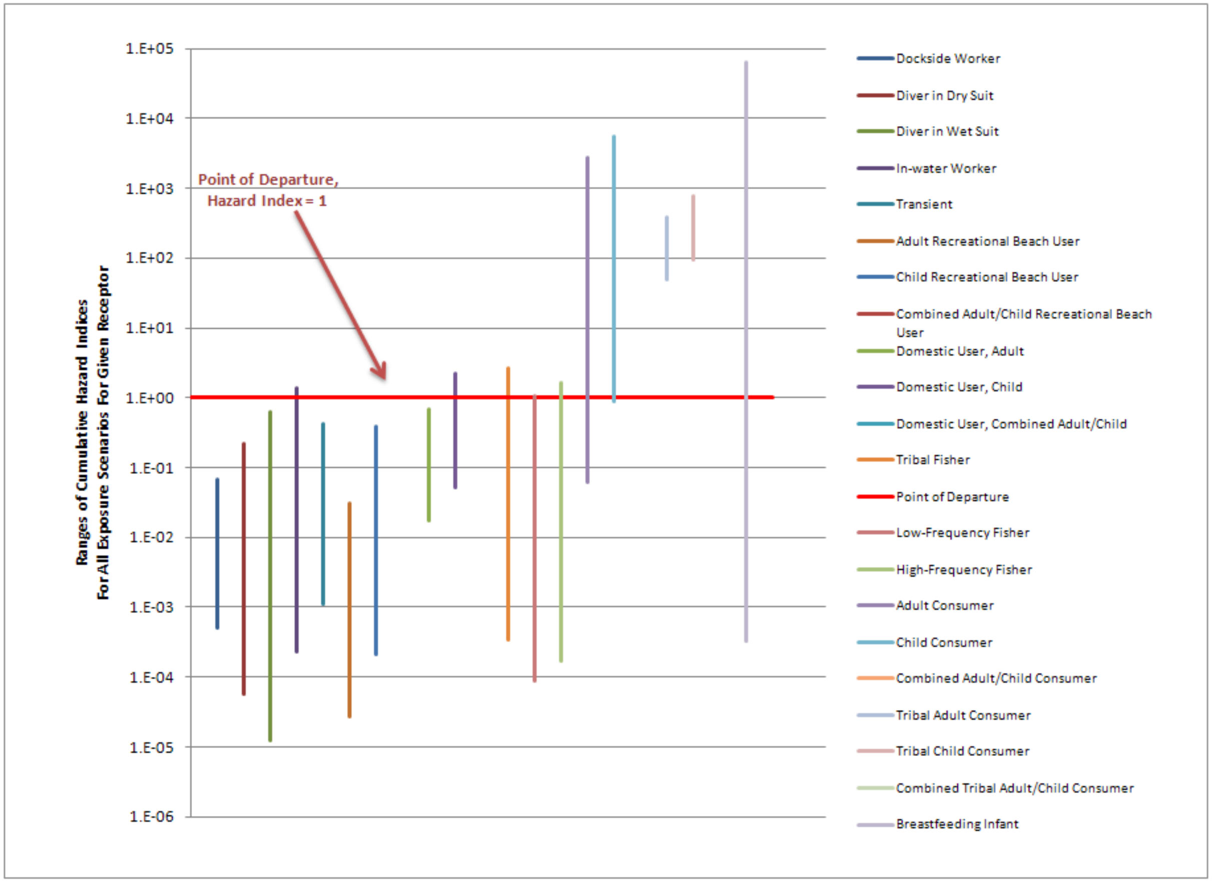
Figure ES-4. Ranges of Cumulative Noncancer Hazard Indices by Receptor Across All Exposure Media and Scenarios Evaluated



~~ES.6 SUMMARY OF BHHRA~~

~~The following presents the major findings of the BHHRA:~~

- ~~Risks resulting from the consumption of fish or shellfish are generally orders of magnitude higher than risk resulting from direct contact with sediment, surface water, or seeps.~~ ~~Risks from fish and shellfish consumption exceed the EPA point of departure for cancer risk of 1 x~~ x ~~10~~$^{-6}$~~, as well as the target cancer risk range of 1 x~~ x ~~10~~$^{-6}$ ~~to 1 x~~ x ~~10~~$^{-4}$ ~~and target HI of 1.~~ ~~With the exception of two ½-mile river segments for the tribal fisher scenario and one location for the hypothetical use of untreated surface water as a drinking water source by a future resident, all of the direct contact scenarios result in risks within or below the EPA target cancer risk range of 1 x~~ x ~~10~~$^{-6}$ ~~to 1 x~~ x ~~10~~$^{-4}$~~.~~ ~~The direct contact scenarios also result in non-cancer hazards below the target HI of 1, with the exception of one ½-river mile segment for in-water sediment and one location for hypothetical use of untreated surface water as a drinking water source.~~

- ~~Fish consumption results in the highest risks of the scenarios evaluated in the BHHRA.~~ ~~PCBs are the primary contributor to risk for fish consumption, and dioxins/furans are a secondary contributor for fish consumption for exposure occurring over the full length of the Study Area.~~ ~~Other contaminants potentially posing unacceptable risks at a Study Area-wide or localized scale for at least one fish consumption exposure scenario include the following contaminants:~~
  - ~~antimony~~
  - ~~arsenic~~
  - ~~lead~~
  - ~~mercury~~
  - ~~selenium~~
  - ~~zinc~~
  - ~~benzo(a)anthracene~~
  - ~~benzo(a)pyrene~~
  - ~~dibenzo(a,h)anthracene~~
  - ~~total carcinogenic PAHs~~
  - ~~bis(2-ethylhexy) phthalate~~
  - ~~hexachlorobenzene~~
  - ~~total PCBs and PCB TEQ~~
  - ~~total dioxin TEQ~~
  - ~~aldrin~~
  - ~~dieldrin~~
  - ~~heptachlor epoxide~~
  - ~~total chlordane~~

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- ~~total DDD~~
- ~~total DDE~~
- ~~total DDT~~
- ~~PBDEs~~

- ~~Risks from PCBs based on consumption of fish within the Study Area exceed the EPA target risk range of 1 x x 10^-6 to 1 x x 10^-4, with a maximum estimated risk of 7 x x 10^-2 (combined adult and child receptor). . The maximum cumulative hazard index from fish consumption is 5,000 (child receptor), primarily from exposure to PCBs in whole body tissue. . The maximum cumulative hazard index from consumption of fillet fish tissue is 4,000 (child receptor), also primarily from exposure to PCBs.~~

~~The body of information available regarding fish consumption rates, both nationally and regionally, indicates that the fish ingestion rates used in the BHHRA address a range of exposures that might occur for consumers of locally caught fish in Portland Harbor, including high fish consuming populations. .~~
~~Concentrations of bioaccumulative chemicals are higher at the Site than in regional tissue. . However, on a regional basis, risks from exposure to bioaccumulative chemicals in tissue exceed EPA target risk levels. . For example, the PCB concentrations detected in resident fish from the Willamette and Columbia Rivers are approximately 20 to 100 times higher than the EPA target fish tissue concentration, when adjusted for the ingestion rates used in this BHHRA and based on a target risk level of 1 x x 10^-6. Regional efforts are underway to reduce fish tissue concentrations. . Sources contributing to regional tissue concentrations are unknown. . The contribution of background sources of contaminants potentially posing unacceptable risks is an important consideration in risk management decisions. . For example, arsenic concentrations in beach sediment contribute approximately 50% percent of cumulative risk from exposure to this medium for the highest-risk scenarios, yet arsenic concentrations detected in beach sediment within the Study Area are comparable to Oregon DEQ-established background levels.~~

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1.0 INTRODUCTION

This Baseline Human Health Risk Assessment (BHHRA) presents ~~the Lower Willamette Group's (LWG's)~~an evaluation of risks to human health ~~for~~ at the Portland Harbor Superfund Site (Site) in Portland, Oregon. This BHHRA is intended to provide an assessment of potential exposures baseline human health risks ~~for the~~due to contaminants at the Site and to support risk management decisions ~~for the Site.~~ .

Portland Harbor encompasses the ~~authorized navigation channel in the~~ Lower Willamette River (LWR) in Portland, Oregon, from the confluence with the Columbia to about River Mile (RM~~)~~) ~~11.8~~12~~.~~ . ~~Portland Harbor~~It has been the focus of numerous environmental investigations completed by the LWG and various other governmental and private entities~~.~~ . Major LWG data collection efforts occurred during ~~three~~ four sampling rounds in the Remedial Investigation/Feasibility Study (RI/FS) Study Area (~~RM~~ RM ~~1.9~~0.8 to ~~11.8~~12.2) to characterize the physical system of the river and to assess the nature and extent of contamination in sediment, surface water, transition zone water, sto~~rm RM~~rm-water, and biota~~.~~ . ~~This BHHRA incorporates the results of these environmental investigations and builds from the initial Human Health Risk Assessment (HHRA) performed as part of the Portland Harbor RI/FS Comprehensive Round 2 Site Characterization Summary and Data Gaps Analysis Report (Round 2 Report) (Integral et. al. 2007).~~

The LWG has worked with the United States Environmental Protection Agency (EPA) to develop the methods and assumptions used in this BHHRA~~.~~ . ~~At the direction of EPA~~Consistent with EPA guidance (1989), this BHHRA incorporates assumptions to provide a health protective assessment of risks associated with contaminants present at the Site~~, which is consistent with EPA guidance on risk assessment (1989)~~. ~~For many of the exposure scenarios evaluated in this BHHRA, upper-bound literature values are used to quantify exposure due to the lack of site-specific exposure information. In some cases, the maximum detected concentrations are used to quantify long-term exposures, which may not be representative of ongoing exposures in the Study Area. Therefore, the results of the BHHRA have a margin of conservatism built into the risk conclusions consistent with EPA guidance (1989).~~ The risk assessment for Portland ~~H~~harbor is a baseline risk assessment in that it evaluates human health risks and hazards associated with contamination in the absence of remedial actions or institutional controls.

This BHHRA is being conducted as part of the Remedial Investigation Report (RI Report) to evaluate potential adverse health effects caused by hazardous substance releases at the Site, consistent with the requirements of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)~~.~~ . The BHHRA will be used to support the development of contaminant thresholds to be used as preliminary remediation goals (PRGs) for sediment~~.~~ . ~~The BHHRA PRGs~~

~~are provided along with PRGs developed under the baseline ecological risk assessment (BERA) for the Site.~~ . The PRGs will provide preliminary estimates of the long-terms goals to be achieved by any cleanup actions in Portland Harbor~~.~~ . During the feasibility study (FS) process, the PRGs will be refined based on background sediment quality, technical feasibility, and other risk management considerations~~.~~ . EPA will identify the final remediation goals (RGs) for the site in the Record of Decision, following completion of the FS.

1.1 OBJECTIVES

The general objective of ~~a HHRA~~a human health risk assessment in the CERCLA process is to ~~assess the potential~~provide an analysis of potential baseline risks to human health from ~~exposure to chemicals present in or entering into environmental media (i.e., water or sediment) or bioaccumulating in the food chain. The overall objective of this BHHRA for the Site is~~ , and ~~to evaluate whether exposure~~ site-related contaminants and help determine the need for remedial actions, provide a basis for determining contaminant concentrations that can remain onsite and still be protective of public health, and provide a basis for comparing the effectiveness of various remedial alternatives.~~to site-related contaminants in sediment, surface water, groundwater seeps, or biota may result in unacceptable risks to human health.~~ To achieve the overall objectives, the general process of BHHRA ~~following are specific objectives of this~~is ~~BHHRA~~:

- Identify contaminants of potential concern (COPCs)[4] ~~for human health~~
- Identify potentially exposed populations and ~~exposure~~ pathways of exposure to ~~populations~~ COPCs ~~who may contact COPCs~~
- Characterize potentially exposed populations and estimate the extent of their exposure to COPCs
- Quantitatively characterize the noncarcinogenic and carcinogenic risks to the populations resulting from potential exposure to COPCs and identify contaminants potentially posing unacceptable risks
- Characterize uncertainties associated with this risk assessment
- Identify the contaminants and pathways that contribute the majority of the risk.

1.2 APPROACH

This BHHRA generally follows the approach that was documented in the Programmatic Work Plan (Integral et al. 2004) and subsequent interim deliverables~~.~~ .

[4] Prior deliverables and some of the tables and figures attached to this document may use the te~~rm~~ RM "Chemicals of potential concern," which has the same meaning as "Contaminants of potential concern" and refers to "contaminants" as defined in 42 USC 9601(33).

It also reflects numerous discussions and agreements on appropriate risk assessment techniques for the Site among interested parties, including the EPA, Oregon Department of Environmental Quality (DEQ), Oregon Department of Human Services (ODHS), and Native American Tribes~~. ~~.

~~Most of the e~~P~~xposure scenarios, including p~~otential exposure pathways~~ and~~, ~~potentially exposed~~ populations, and exposure assumptions were originally identified in the Programmatic Work Plan~~. ~~. ~~Most of the assumptions used to estimate the extent of exposure for these scenarios were also identified in the Programmatic Work Plan.~~ Additional assumptions for estimating the extent of exposure were provided in the Exposure Point Concentration Calculation Approach and Summary of Exposure Factors Technical Memorandum (Kennedy/Jenks Consultants 2006) and the Human Health Toxicity Values Interim Deliverable (Kennedy/Jenks Consultants 2004a)~~. ~~. ~~Exposure scenarios that were not included in the Programmatic Work Plan were evaluated in this BHHRA based on direction from EPA.~~ Specific ~~agreements with and direction from EPA~~documents related to the approach for this BHHRA are ~~documented~~ presented in Attachment F1~~. ~~.

The ~~approach of this~~ BHHRA is based on EPA (1989, 1991b, 2001a, 2004, 2005a) and EPA Region 10 (2000a) guidance~~ and direction from EPA~~, ~~. The approach~~ and is also consistent with DEQ guidance ~~for HHRAs~~ (DEQ 2000a, 2010).

1.3 SITE BACKGROUND

The LWR extends from the Willamette's convergence with the Columbia River at river mile (RM~~)~~) 0 upstream to the Willamette Falls at ~~RM~~ RM 26~~. ~~. Portland Harbor generally refers to a heavily industrialized reach of the LWR between ~~RM RM~~ RM 0 and ~~RM RM~~ RM ~~11.8~~12, the extent of the navigation channel~~. ~~. Additional information on the environmental setting of Portland Harbor, including historical and current land use, regional geology and hydrogeology, surface water hydrology, the in-water physical system, habitat, and human access and use is provided in Section 3 of the RI Report~~. ~~. The approximate ~~10~~11-mile portion of Portland Harbor from ~~RM~~ RM ~~1.9~~0.8 to ~~11.8~~12.2 is referred to as the Study Area (Map 1-1)~~. ~~. Because the Site boundaries have not yet been defined[5], this BHHRA focused on the Study Area.

Portland Harbor and the Willamette River have served as a major industrial water corridor for more than a century.~~ ~~ Industrial use of the Study Area and adjacent areas has been extensive.~~ ~~ The majority of the Study Area is currently zoned for industrial land use and is designated as an "Industrial Sanctuary" (City of Portland 2006a). Much of the shoreline in the Study Area includes steeply sloped banks covered with riprap or constructed bulkheads, with human-made structures such as piers and wharves over the water in various locations.~~ ~~ A comprehensive update of Portland's

[5] The Site boundaries will be defined by EPA in the Record of Decision for the Site.

Willamette Greenway Plan and related land use policies and zoning (The River Plan) is underway, addressing all of the Willamette riverfront in Portland (City of Portland 2006b). The Willamette Greenway Plan addresses the quality of the natural and human environment along the Willamette River and generally includes all land adjacent to the river, public lands near the river, and land necessary for conservation of significant riparian habitat. (The Willamette Greenway Plan, adopted by the City Council November 5, 1987, Ordinance 160237). The Greenway Plan is intended to “protect, conserve, enhance, and maintain the natural, scenic, historical, economic, and recreational qualities of lands along Portland’s rivers.” (Portland City Code Chapter 33.440). The Plan supports industrial uses within Portland Harbor while at the same time looks to increase public access to the river. As a result, recreational use within the Study Area may increase at certain locations in the future.

There are numerous potential human uses of Portland Harbor. Worker activities occur at the industrial and commercial facilities in the Study Area. However, due to the sparse beach areas and high docks associated with most of the facilities, worker exposure to the in-water portion of the Study Area may be limited in shoreline areas. Commercial diving activities also occur in the LWR.

In addition, the LWR provides many natural areas and recreational opportunities, both within the river itself and along the riverbanks. Within the Study Area, Cathedral Park, located ~~under th~~adjacent to the~~e~~ St. Johns Bridge, includes a sandy beach area and a public boat ramp and is used for water skiing, occasional swimming, and waterfront recreation. Recreational beach use also may occur within Willamette Cove, ~~which is a riverfront natural area, in~~ Swan Island Lagoon, and on the southern end of Sauvie Island~~, which is within the Study Area~~. Swan Island Lagoon includes a public boat ramp. Additional LWR recreational beach areas exist on the northern end of Sauvie Island and in Kelley Point Park, both of which are outside of the Study Area.

Fishing is conducted throughout the LWR basin and within the Study Area, both by boaters and from locations along the banks. The LWR also provides a ceremonial and subsistence fishery for Pacific lamprey (particularly at Willamette Falls) and spring Chinook salmon for Native American Tribes. Many areas in the LWR are also important currently for cultural and spiritual uses by local Native Americans.

Transients have been observed along the LWR, including some locations within the Study Area. The observation of tents and makeshift dwellings during RI sampling events confirms that transients were living along some riverbank areas. Transients are expected to continue to utilize this area in the future.

The RI/FS being completed for the Site is designed to be an iterative process that addresses the relationships among the factors that may affect chemical distribution, risk estimates, and remedy selection. ~~Three~~ Four rounds of field investigations have been completed as part of the RI/FS~~—~~. A preliminary sampling effort was conducted in 2001 and 2002 prior to the RI/FS work plan. Round 1 was conducted in 2002 and focused primarily on chemical concentrations in fish and shellfish tissue and in beach sediment~~—~~. Round 2 was conducted in 2004 and 2005 and focused on chemical concentrations in sediment cores, in-water surface sediment, surface water, transition zone water, and additional shellfish tissue and beach sediment~~—~~. Round 3 was conducted in 2006 and 2007 and focused on chemical concentrations in additional surface water, sediment, and fish and shellfish tissue~~—~~. These Round 1, Round 2, and Round 3 sampling efforts, while initially focused on ~~RM~~ RM 3.5 to 9.2, which is the Administrative Order on Consent-defined initial study area (ISA), extended well beyond the ISA to ~~RM~~ RM 0 downstream and to ~~RM~~ RM ~~19~~ 28.4 upstream~~—~~.

1.4 ORGANIZATION

In accordance with guidance from EPA (1989), which is consistent with DEQ guidance (2000a, 2010), the BHHRA incorporates the four steps of the baseline risk assessment process: data collection and evaluation, exposure assessment, toxicity assessment, ~~and~~ risk characterization, as well as a discussion of overall uncertainties. ~~(which includes an uncertainty assessment).~~

This BHHRA is organized as follows:

- Section 2, Data Evaluation – This section evaluates the available data for the Study Area and identifies the COPCs for further evaluation in the BHHRA.
- Section 3, Exposure Assessment – This section presents potentially complete routes of exposure and potentially ~~receptor~~ exposed populations for further evaluation in the BHHRA, which are summarized in the conceptual site model (CSM).
- Section 4, Toxicity Assessment – This section evaluates the potential hazard and toxicity of the COPCs selected for quantitative evaluation in this BHHRA.
- Section 5, Risk Characterization – This section presents the cancer risks and noncancer hazards and identifies the contaminants potentially posing unacceptable risks to human health.
- Section 6, Uncertainty Analysis – This section discusses the uncertainties that are inherent in performing a HHRA, and the uncertainties specific to this BHHRA.
- Section 7, Summary – This section summarizes the findings of this BHHRA and identifies chemicals and pathways that contribute the majority of the risk within the Study Area.
- Section 8, Conclusions – This section provides the conclusions for this BHHRA.

- Section 9, References – This section lists the references used in this BHHRA.

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2.0 DATA EVALUATION

This section presents the data that were used in this BHHRA and the results of the selection of COPCs in sediment, water, and tissue~~.~~. The LWG and non-LWG sampling events included in the site characterization and risk assessment (SCRA) dataset are described in detail in ~~Section 2.0~~Appendix A of the RI Report~~.~~. The ~~BHHRA~~ dataset used in this BHHRA represents a subset of data from the sampling events that comprised the SCRA dataset as of September 2008~~.~~. Data needs for the BHHRA were identified through the data quality objective (DQO) process described in Section 7 of the Programmatic Work Plan (Integral et al~~.~~. 2004).~~Data collection and evaluation included the gathering and analysis of data relevant to human exposures and the identification of those contaminants that are the focus of this BHHRA.~~ Only data that -met Category 1/QA2 data quality objectives was used in the BHHRA.~~Data needs for the BHHRA were identified through the data quality objective (DQO) process described in Section 7 of the Programmatic Work Plan (Integral et al. 2004).~~ A

~~This section presents the data that were used in this BHHRA and the results of the selection of COPCs in sediment, water, and tissue. The LWG sampling events and non-LWG sampling events included in the site characterization and risk assessment (SCRA) dataset are described in detail in Section 2.0 of the RI Report. The BHHRA dataset used in this risk analysis and described in this section is a subset of data from the sampling events that comprised the SCRA dataset as of September 2008. Additional information on the BHHRA dataset and details on the use of the data in the BHHRA are provided in Attachment F2. In addition, per EPA comments on the draft BHHRA [note: why?], a~~ risk evaluation ~~of potential~~of exposures to polybrominated diphenyl ethers (PBDEs) ~~in~~ detected in in-water sediment, fish ~~tissue,~~ and shellfish tissue was ~~performed~~ conducted ~~at the direction of EPA~~ using a subset of data from the sampling events that comprised the SCRA dataset as of February 2011~~.~~. The data for the PBDE analysis are discussed in Attachment F3, and the PBDE risk assessment used the general data evaluation methodology discussed in this section.

2.1 AVAILABLE DATA

The ~~risk characterization~~ BHHRA dataset includes only those matrices relevant for direct human ~~health~~ exposure pathways ~~that were quantitatively evaluated~~: surface sediment ~~[(0 to 30.5 centimeter (cm) in depth])~~, clam and crayfish tissue, fish tissue, surface water and groundwater seeps~~.~~. Other matrices included in the SCRA dataset (~~e~~such as~~.g.,~~ subsurface sediment) were not evaluated in the BHHRA because ~~they were not relevant to the exposure scenarios evaluated~~human exposure was considered unlikely ~~(see Section 3).~~. ~~Although the BHHRA focused on the Study Area, additional data~~ Data from ~~outside the Study Area, from downstream to RM~~ RM 1.0, including Multnomah Channel, and upstream to ~~RM~~ RM 12.2, were included in the risk assessment~~also used to assess risk, per an agreement with EPA.~~

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. The BHHRA dataset is ~~divided into samples collected within the Study Area and outside of the Study Area, and and is~~ summarized by matrix in ~~Tables~~ Tables 2~~-~~-1~~1 and 2-~~-2. The dataset is described briefly in the following subsections, and described in more detail in Section 2.0 of the RI Report~~.~~.

2.1.1 Beach Sediment

~~The Programmatic Work Plan identified Areas~~ ~~a~~Areas where potential exposure to beach sediment could occur were ~~identified and designated as human use areas in the Programmatic Work Plan. Human use areas were designated~~ based only on current conditions, as identified in the Programmatic Work Plan~~.~~. Because ~~Beaches~~ beaches are relatively dynamic environments~~;~~, specific ~~if~~ beach conditions may change in the future~~, additional risk evaluation of the human use areas may be required~~, and the evaluation presented in the BHHRA may no longer be appropriately descriptive of potential risks~~.~~.

Composite sediment samples were collected during Round 1 from each beach that had been designated as a potential human use area within the Initial Study Area (ISA)~~.~~. Additional human use areas within the Study Area but downstream of the ISA were sampled during Round 2 as part of the sampling of shorebird habitat~~. All of the Round 1 beach samples and the six Round 2 beach samples that were collected from potential human use areas located downstream of the ISA~~ were also included in the BHHRA dataset~~.~~. The designated potential human use areas and associated beach sediment samples are shown in Map 2-1, and ~~.~~Table 2-~~3~~ 2 presents a summary of the ~~beach~~ composite sediment samples included in the BHHRA dataset~~.~~.

2.1.2 In-Water Sediment

~~In~~The in-water sediment BHHRA dataset includes samples collected outside of the navigation channel of the river and from less than 30.5 cm in depth~~,~~~~.~~. Beach sediment samples ~~It~~are excludesd ~~beach sediment samples~~, as well as natural attenuation core samples, radioisotope samples, and samples collected from areas that were subsequently dredged~~.~~.

The in-water sediment dataset is ~~divided into two subsets:distinguished as data collected either within andor outside of the study area. .~~ comprised of ~~Data~~samples collected within the study area includes ~~in-water sediment~~ samples from river mile (RM) 1 ~~.9~~ to ~~RM~~ RM ~~11.8~~12.2, including Swan Island Lagoon, as well as samples from the mouth of Multnomah Channel ~~that were included in the study area for the Round 2 Report. . Data outside the study area includes samples collected from RM RM 1 to RM RM 1.9, from RM RM 11.8 to RM RM 12.2, and from Multnomah Channel areas outside of the sStudy aArea.~~ . As described in Appendix A of the RI, samples collected from areas that have subsequently been capped or dredged were not included in the BHHRA dataset ~~because these samples are no longer representative of current conditions.~~ . Per an agreement with EPA, ~~T~~the screening

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of contaminants of potential concern (COPCs) used only the subset of data ~~containing samples within the study area~~collected from RM 1.9 to RM 11.8 (and including Swan Island Lagoon and the mouth of Multnomah Channel), whereas the exposure assessment and risk characterization used both subsets of data containing samples from ~~within and outside the study area,~~RM- 1 to RM 12.2~~ per an agreement with EPA. ~~. A summary of in-water sediment samples ~~collected within the Study Area and ~~included in the BHHRA dataset is presented in Table 2-3~~, samples collected outside the Study Area are presented in Table 2-4.~~~~surface sediment chemistry data in the BHHRA dataset include LWG collected data (from Rounds 1, 2, and 3) and non-LWG collected data. Tables 2-3 and 2-4 present a summary of the surface sediment samples both within the Study Area and outside of the Study Area that are included in the BHHRA dataset. All non-LWG data included in the BHHRA dataset (see Section 2.0 of the RI Report) met the data quality requirements for risk evaluation (Category 1/QA2), as agreed to between LWG, EPA, and EPA's partners in the Programmatic Work Plan (Integral et al. 2004).~~

~~All in-water surface sediment data included in the BHHRA dataset were collected from the top 30.5 cm in depth, outside of the navigation channel of the river. Samples from within the Study Area were located throughout its entire length (RM 1.9 to RM 11.8), and samples outside of the Study Area extended downstream to RM 1.0, including Multnomah Channel, and upstream to RM 12.2. Surface sediment samples that were collected from areas that have been characterized in the SCRA as capped or dredged were not included in the BHHRA dataset because these samples are no longer representative of the current conditions in the Study Area. A more detailed description of the in-water sediment dataset used in this BHHRA is provided in Attachment F2; a description of samples that have been characterized as capped or dredged in the SCRA is provided in Appendix A of the RI Report.~~

2.1.3 Surface Water

~~To capture seasonal water flow conditions on the LWR, S~~Ssurface water samples were collected by the LWG in seven separate events during Rounds 2 and 3 between 2004 and 2007, and are representative of various seasonal water flow conditions.~~Surface water data were collected by the LWG during Rounds 2 and 3, as described in Appendix A of the RI Report. All Round 2 and Round 3 surface water data between RM 1.9 and 11.8, as well as samples collected from Multnomah Channel, were included in the BHHRA dataset. The use of the surface water dataset in evaluating different human exposure scenarios is discussed in subsequent sections and in Attachment F2. Surface water sampling was performed in seven separate events between 2004 and 2007 to capture the seasonal water flow conditions on the LWR. Tables 2-5 and 2-6 present a summary of the surface water samples included in the BHHRA dataset from within and outside of the Study Area.~~

~~Amongst all seven sampling events,~~S~~ 37 ~~sample~~urface water locations were sampled between RM 1.9 and RM 11.8, and were included in the BHHRA dataset.~~

Surface water samples were collected between ~~RM~~ RM 1.9 and ~~RM~~ RM 11.8 ~~in the BHHRA dataset were collected~~ from 32 single point stations and 5 transect locations (at ~~RM~~ RM 2.0, Multnomah Channel, ~~RM~~ RM 3.9, ~~RM~~ RM 6.3, and ~~RM~~ RM 11)~~.~~. One additional surface water sample was collected from ~~RM~~ RM 16, outside the boundaries of the Study Area~~.~~. Surface water samples were collected ~~with~~ using either a peristaltic pump or an XAD-2 Infiltrex™ 300 system (XAD)~~.~~. Single point samples included near-bottom and near-surface samples, as well as vertically integrated water column samples~~.~~. Transect samples included horizontally integrated near-bottom and near-surface samples, cross-sectional equal discharge increment samples ~~(i.e., samples~~ horizontally integrated across the entire width of the river ~~into a single sample for either near-surface or near-bottom horizontally integrated samples)~~, and vertically integrated samples from the east, west, and middle sections of a transect on the river~~.~~. Additional information on the surface water sampling methods is available in Section 5.3 of the RI Report. Tables 2-5 and 2-6 present a summary of the surface water samples included in the BHHRA dataset from within and outside of the Study Area, respectively.

2.1.4 Groundwater Seeps

A seep reconnaissance survey was conducted during Round 1 to document readily identifiable groundwater seeps along ~~approximately 17 miles of~~both sides of the river~~bank~~ from ~~RM~~ RM 2 to 10.5 (GSI 2003)~~.~~. Twelve potential groundwater seeps were observed at or near ~~a~~ potential human use beach areas~~.~~. Of these, only three sites were identified in the survey where it was considered likely for upland contaminants of interest (COIs)[6] to reach groundwater seeps or other surface expressions of groundwater discharging to human use beaches ~~(GSI 2003):),~~: the City of Portland sto~~rm RM~~rm-sewer Outfall 22B, Willbridge, and McCormick and Baxter ~~(~~at Willamette Cove~~).~~.

Of the ~~three potential groundwater seep areas~~se locations, only the Outfall 22B discharge was evaluated in ~~this~~ the BHHRA~~.~~. ~~At this location, g~~Groundwater infiltrates into the outfall pipe, which subsequently discharges to a beach~~. The beach where Outfall 22B discharges was~~ that has been identified as a potential transient use area~~, so exposure to the groundwater seep in that beach by transients is considered a potentially complete pathway.~~. The groundwater seep ~~identified~~ at Willbridge is ~~in~~ at a beach restricted to industrial use~~, and exposure to groundwater seeps is considered an incomplete pathway for workers.~~ ~~The~~ the ~~groundwater~~ seep ~~identified during the seep survey (GSI 2003)~~at ~~in~~ Willamette Cove, located downgradient of the McCormick and Baxter Superfund Site, was capped during remedial activities in 2004.

The stormwater pipeline that discharges at Outfall 22B provides a conduit for surface discharge of groundwater containing COIs that infiltrates into the pipe upland of the beach~~.~~. The sampling events at Outfall 22B are described in Appendix A of the RI

[6] Prior deliverables and some of the tables and figures attached to this document may use the te~~rm~~ RM "Chemicals of interest," which has the same meaning as "Contaminants of interest" and refers to "contaminants" as defined in 42 USC 9601(33).

Report~~—~~. ~~Samples~~ Although samples have periodically been collected for analysis of the discharge at Outfall 22B ~~have periodically been collected for analysis,~~ both during ~~stormwater events~~ and outside of stormwater events, ~~-~~ samples taken during stormwater events were not included in the BHHRA dataset because they were not considered representative of typical exposures.~~In order to represent potential exposure from the groundwater seep, samples taken during stormwater events were not included in the BHHRA dataset. The data from Outfall 22B met the data quality requirements for risk evaluation (Category 1/QA2), and the results of this sampling were included in the SCRA database.~~ Samples ~~taken~~ collected since 2002 were used in the BHHRA, and~~.~~ Table 2-5 presents a summary of the samples ~~from Outfall 22B~~ that were included in the BHHRA dataset~~—~~. ~~The BHHRA Outfall 22B dataset is further described in Attachment F2. The sampling events for this data are described in Appendix A of the RI Report.~~

2.1.5 Fish Tissue

The target fish species to be evaluated for human consumption were identified in the Programmatic Work Plan (Integral et al~~—~~. 2004~~).~~), and consisted of both resident and non-resident species~~—~~.– Samples ~~Resident~~ of resident fish species ~~samples~~ were collected by the LWG during Rounds 1 and 3 ~~by the LWG.~~ . ~~In addition, adult white sturgeon (*Acipenser transmontanus*), adult spring Chinook salmon (*Oncorhynchus tshawytscha*), and adult Pacific lamprey (*Lampetra tridentate*) were~~Samples of non-resident fish species were ~~-~~collected in the summer of 2003 through a cooperative effort of the ODHS, Agency for Toxic Substances and Disease Registry (ATSDR), Oregon Department of Fish and Wildlife (ODFW), the City of Portland and EPA Region 10. ~~(This sampling effort is referred to as the "ODHS Study" in the rest of this BHHRA).~~ Table 2-7 presents a summary of the fish tissue samples included in the BHHRA dataset.

2.1.5.1 Resident Fish Tissue

Resident fish species evaluated in the BHHRA are ~~Smallmouth~~ smallmouth bass (*Micropterus dolomieui*), black crappie (*Pomoxis nigromaculatus)*, common carp (*Cyprinus carpio carpio)*, and brown bullhead (*Ameiurus nebulosus*) ~~were the resident fish species collected and analyzed to support the BHHRA.~~ . The sampling ~~design~~ protocol for each species differed ~~was~~ based on the reported home ranges of ~~the target fish~~species sampled~~—~~. ~~, so the sampling approach differed based on species. For~~T~~Round 1 data collection, t~~he tissue compositing scheme for the Round 1 data collection ~~for each sample~~effort was reviewed and approved by EPA in November and December 2002 ~~prior to laboratory analysis.~~ . The Round 3 data collection, the tissue compositing scheme was approved by EPA in October 2007~~—~~. Smallmouth bass and carp collected during Round 3 were analyzed separately as fillet and the remaining body-without-fillet tissue, and whole body concentrations were calculated using the individual fillet and body-without-fillet results~~—~~. Thus, for the risk assessment, the Round 3 smallmouth bass samples were reported both as fillet and whole body results~~—~~. ~~The For Round 3~~

~~data collection, the tissue compositing scheme for each sample was reviewed and approved by EPA in October 2007 prior to laboratory analysis.~~

~~During~~ S~~Round 1, s~~mallmouth bass samples were collected in Round 1 from eight locations between ~~RM~~ RM 2 and 9, and corresponding to their small home range (ODFW 2005), and ~~each corresponding to approximately one river mile. Smallmouth bass were collected and~~ composited based on each river mile~~ locations due to their small home range relative to the other fish collected during Round 1.~~ . Three whole body replicate composite samples were collected at three of the eight ~~river mile~~ locations~~. At each of the remaining five river mile locations,~~, one whole body composite sample and one fillet composite sample were collected at the 5 remaining sample locations~~. ~~. ~~All Round 1 results from within the Study Area were included in the BHHRA dataset.~~

~~During~~ Round 3~~, smallmouth bass~~samples were collected from 18 stations between ~~RM~~ RM 2 and 12, each corresponding to approximately one river mile, ~~and~~ either the west or east ~~portion~~ side of the river, or both~~. ~~. One composite sample was collected from each station, typically consisting of five individual fish~~. ~~. ~~for which Ffillet and the remaining tissue and remainder tissue (body -without without fillet) tissue were analyzed separately, and whole body concentrations were calculated using the individual fillet and body-without-fillet results. Thus, for the risk assessment, the Round 3 smallmouth bass samples were reported as fillet and whole body results.~~ . ~~All Round 3 results were included in the BHHRA dataset.~~

B~~During Round 1, b~~lack crappie, common carp, and brown bullhead samples were collected during Round 1 and composited ~~for~~ from two three-mile long fishing zones, ~~RM~~ RM 3-6 and ~~RM~~ RM 6-9~~each approximately three river miles in length (RM 3-6 and RM 6-9).~~ . Three common carp and brown bullhead whole body and ~~three~~ fillet replicate composite samples were collected ~~at~~ from each ~~of the two fishing~~ zone~~s for common carp and brown bullhead.~~ . Two black crappie whole body and ~~two~~ fillet replicate composite samples were collected within each ~~of the fishing~~ zone~~s for black crappie.~~ . All ~~Round 1~~ results from within the Study Area were included in the BHHRA dataset.

During Round 3, common carp samples were collected ~~for~~ from three fishing zones, each approximately four river miles in length (~~RM~~ RM 0-4, ~~RM~~ RM 4-8, and ~~RM~~ RM 8-12)~~. ~~. Three common carp composite samples were collected from each fishing zone and analyzed separately as fillet tissue and ~~remainder~~ body-without-fillet tissue~~. ~~. All Round 3 results were included in the BHHRA dataset.

S~~For s~~mallmouth bass, black crappie, and common carp~~, all~~ fillet samples were analyzed as fillet with skin, except for the analysis of mercury, which was performed using fillet without skin~~. ~~. B~~For b~~rown bullhead~~, all~~ fillet samples were analyzed as fillet without skin.

2.1.5.2 Salmon, Lamprey, and Sturgeon

Adult white sturgeon (*Acipenser transmontanus*), adult spring Chinook salmon (*Oncorhynchus tshawytscha*), and adult Pacific lamprey (*Lampetra tridentate*)~~The tissue data collected during the~~ -were collected during ODHS Study~~, .~~ ~~were the only non-LWG fish tissue data of acceptable data quality for risk evaluation (Category 1/QA2).~~ Although these data were not collected as part of the RI, ~~they~~ the data met Category 1/QA2 data quality requirement s and were evaluated by the LWG and used in this BHHRA~~.~~.

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~~, adult white sturgeon (*Acipenser transmontanus*), adult spring Chinook salmon (*Oncorhynchus tshawytscha*), and adult Pacific lamprey (*Lampetra tridentate*)A~~

~~The a~~dult Chinook salmon samples were collected at the Clackamas fish hatchery~~.~~. ~~Whole body, fillet with skin, and fillet without skin composite samples were analyzed.~~ Each composite sample ~~included~~consisted of three individual fish~~three individual fish.~~ . Five ~~whole~~ whole-body~~composite sample~~ (~~s,~~ including one split), three fillet with skin, and three fillet without skin composite samples were analyzed~~.~~. The fillet without skin composite samples were only analyzed for dioxin, furan, and polychlorinated biphenyl (PCB) congeners and mercury.

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A~~The a~~dult Pacific lamprey samples were collected at the Willamette Falls. ~~Only whole body composite samples were analyzed.~~ Four whole body composite samples, e~~E~~ach ~~composite sample included~~ consisting of 30 individual fish,~~.~~ ~~Four whole body composite samples~~ were analyzed~~.~~.

A~~The a~~dult sturgeon samples were collected between ~~RM~~ RM 3.5 and 9.2~~.~~. ~~Only fillet without skin samples were analyzed. Each sample was an individual fish.~~ Six fillet samples were analyzed without skin~~,~~ (including one split), each sample consisting of a single fish~~, were analyzed~~.

2.1.6 Shellfish Tissue

~~Shellfish tissue in the BHHRA dataset included field-collected samples for Ccrayfish and clam (*Corbicula* sp.) tissue samples were collected and included in the BHHRA dataset. Crayfish samples were collected during Rounds 1 and 3 and clam samples were collected during Rounds 1, 2, and 3. Although data from laboratory bioaccumulation samples were also available from Round 2, these data were not used because field-collected tissue samples provide for a more direct evaluation of potential human exposure than laboratory bioaccumulation samples. No field-collected, non-LWG shellfish tissue data of acceptable data quality for risk evaluation (Category 1/QA2) were identified. Tables 2-7 and 2-8 present a summary of the shellfish tissue samples included in the BHHRA dataset, from both inside and outside the Study Area, respectively.~~

C~~For c~~rayfish~~,~~ samples were collected from 24 stations during Round 1~~. The Round 1 crayfish stations were selected~~ based on habitat areas~~. Crayfish were collected,~~ and from 9 stations during Round 3~~. The Round 3 crayfish stations were~~ based on habitat areas and data needs identified by the EPA~~ and habitat areas.~~ . Commensurate with their limited home range, ~~Crayfish~~ crayfish were collected and ~~composited~~ analyzed as whole body composite samples from each individual station~~s commensurate with their limited home ranges.~~ . ~~Only whole body composite samples were collected for crayfish.~~ During Round 1, two replicate composite samples were collected at three of the 24 stations~~,~~;~~.~~ ~~A~~a~~t each of the remaining stations, a~~ single composite sample was collected at the remaining stations~~.~~. During Round 3, a single composite sample was collected at each station.

Clams~~For clams, samples~~ (*Corbicula* sp.) were collected from ~~3~~ three stations during Round 1, 33 stations during Round 2, and 10 stations during Round 3~~;~~ ~~.~~, ~~S~~sampling locations were based on habitat areas and biomass availability.~~ Clams were collected and composited from individual stations that were selected based on habitat areas and biomass availability.~~ A single composite sample was collected at each station in Rounds 1 and 2~~.~~. In Round 3, two composite samples were collected from each of five stations, and a single composite sample was collected from each of the remaining five stations~~.~~. ~~Depuration is a common method for cleansing shellfish that is often done prior to human consumption to eliminate the sediment present in the gastrointestinal (GI) tract of the shellfish. The~~ Round 1 and Round 2 ~~field-collected clams~~samples were ~~not depurated prior to analysis~~analyzed undepurated~~, and the data therefore may over predict human health risks from this exposure pathway for consumers that do depurate clams prior to consumption.~~ . ~~In~~ As previously noted, two samples were collected from each sampling station in Round 3~~,~~, one sample from each station was depurated prior to analysis, the other was analyzed undepurated~~.~~. ~~five samples were depurated prior to analysis (depurated samples were from stations where two samples were collected; one sample from each Round 3 station was not depurated). Additional discussion of the potential effects of depuration on human health risks is included in Section 6. All LWG field-collected clam samples were included in the BHHRA dataset.~~ Although data from laboratory bioaccumulation samples were also available from Round 2, these data were not used because field-collected tissue samples provide for a more direct evaluation of potential human exposure than laboratory bioaccumulation samples~~.~~. Tables 2-7 and 2-8 present a summary of the shellfish tissue samples included in the BHHRA dataset, from both inside and outside the Study Area, respectively.

2.2 ~~USE OF DATA~~DATA EVALUATION

Prior to using the data in the BHHRA, the data ~~reduction was conducted~~were evaluated for inclusion in the BHHRA consistent with the Guidelines for Data Reporting, Data Averaging, and Treatment of Non-Detected Values for the Round 1 Database (Kennedy/Jenks Consultants et al~~.~~. 2004), the Exposure Point

Concentration Calculation Approach and Summary of Exposure Factors (Kennedy/Jenks Consultants 2006), and Proposed Data Use Rules and Data Integration for Baseline Human Health Risk Assessment (BHHRA), submitted to EPA in a May 28, 2008 email ~~communication with EPA.~~ . D~~ata reduction and d~~ata use rules applied to the combining of surface water data collected by different methods, the handling of non-detects, the summing of chemical groups, and the calculation of exposure point concentrations (EPCs)~~.~~ . ~~These rules are described in detail in Attachment F2.~~

2.2.1 Excluded Data

The data used BHHRA ~~consists only of data that~~ meet Category 1/QA2 data quality objectives, as described in Section 2.2 of the RI Report~~.~~. Data that were not of this quality were removed from the BHHRA dataset~~.~~. General reductions of the SCRA dataset to create the BHHRA dataset included removal of rejected analytical results (“R” qualified results), and removal of analytical results of samples collected from locations that have been capped, dredged, or remediated. This included all samples flagged as capped, dredged or remediated, including data from task WLCMBI02: the McCormick & Baxter September 2002 Sampling.

2.2.2 Field Replicates

Field replicates within the BHHRA dataset were handled per agreements with EPA~~.~~. When calculating a mean or an upper confidence limit (UCL), and when reporting data in general, replicates were included in the dataset as discrete samples~~.~~. Replicates with unique coordinates were included as separate samples when mapping or spatially weighing data~~.~~. Where replicates have the same coordinates, data associated with the first sample were used and data from the second or third replicates were excluded.

2.2.3 Co-elution of PAHs

Benzo(b+k)fluoranthenes and benzo(k+j)fluoranthenes co-eluted in certain surface water and in-water sediment samples~~.~~. For the purposes of the BHHRA, benzo(b+k)fluoranthenes results were assumed to be completely benzo(b)fluoranthene, and benzo(k+j)fluoranthenes results were assumed to be completely benzo(k)fluoranthene~~.~~. Analytical results for these samples were not presented as co-elutions in the BHHRA, but rather, were presented as results for their assumed analyte.

2.2.4 Treatment of PCB Surface Water Data

Polychlorinated biphenyls (PCBs) were analyzed as Aroclors in samples collected using a peristaltic pump, and as congeners in high-volume samples collected using the XAD-2 sampling method~~.~~. ~~The~~Because detection limits for the peristaltic pump

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2.2.5 ~~2.5.1~~ Combining XAD Column and Filtered Surface Water Data

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The XAD water quality samples consisted of two components: chemicals retained on the column that –are representative of the dissolved concentration, and chemicals retained on the filter that are representative of the concentration of the suspended particulate fraction~~.~~. In order to create a whole water sample from the XAD results, the ~~A~~analytical results for column and filter fractions for a given chemical were combined to give a total concentration~~.~~. The following rules were used ~~to combine the two concentrations measured in the column and filter~~ to calculate a whole water concentration for ~~that~~individual samples:

- If an ~~chemical~~analyte was detected in both the filter and the column, the detected concentrations were summed~~.~~.
- If an ~~chemical~~analyte was detected in either the filter or the column but not in both portions of the sample, only the detected concentration was used.
- If an ~~chemical~~analyte was not detected in both the filter and the column, the highest detection limit reported for either the filter or the column was used~~.~~.

S~~ample IDs for s~~urface water samples collected using the high-volume XAD-2 sampling method ~~contain~~are identified with the letters "XAD."~~.~~ ~~Sample IDs for the~~The results of the combined XAD-2 column and filter data were renamed "WSXAD-Combo," and are presented as such in the BHHRA.

2.2.6 ~~2.5.2~~ Combining Horizontal and Vertical Surface Water Data

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~~For some surface water exposure scenarios, the appropriateWhen evaluating surface water exposures point is thfor divers, transients, and residential/domestic water use, e detected concentrations~~The ~~available~~ surface water data described in Section 2.1.3 were~~entire water column,~~ vertically integrated ~~from bottom to surface~~ prior to use in the BHHRA.~~.~~ T~~In the case ofWhere~~ transect samples ~~were collected, the appropriate exposure point is the concentrations were~~are presented as a vertically and horizontally integrated transect~~.~~. N~~During some of the surface water sampling events, n~~on-integrated samples were collected from both near-bottom and near-surface (NB/NS) depths within the water column at ~~a given~~ single-point sampling locations~~.~~. V~~For some transect locations, v~~ertically-integrated transect samples were collected from the east, west, and middle (E/W/M) sections of the river, ~~or~~ horizontally integrated samples were collected from NB or NS water depths~~.~~. ~~For exposure points representing direct contact with surface water,~~ NB/NS and/or

E/W/M samples from the same location and date were combined to provide an integrated value for the water column or transect~~.~~. In these cases, ~~the~~ single-point data from NB and NS were vertically combined~~;~~, ~~the~~ vertically-integrated data from E/W/M were horizontally combined; and ~~the~~ horizontally-integrated data from NB/NS were vertically combined using the following rules:

- If an ~~chemical~~analyte was detected in each sample, the detected concentrations were averaged ~~and the average was used.~~ .
- If an analyte ~~chemical~~ was detected in at least one sample ~~and not detected in at least one sample~~, ~~the detected~~the mean concentration was calculated using ~~concentration(s) were averaged with ½~~one-half the detection limit ~~of the non-detected concentration(s), and the average was used~~for non-detect results.
- If ~~a chemical was not detected in any of the two or three samples to be combined~~all results were non-detect, ~~the full detection limit of each sample was averaged~~the mean of the detection limits was calculated~~,~~ and ~~the average was~~ used as the non-detected concentration ("U" qualified).
- ~~If a result for a given analyte was rejected or did not exist for any of the two or three samples to be combined, a combined value was not calculated.~~
- In some ~~cases~~instances, a field replicate sample was collected from the middle of the river without corresponding replicate samples from the east or west side of the river, ~~(~~indicated by "M2" in the Sample ID~~).~~. The results from these samples were included in the dataset at their reported concentrations, without combining them with other results.

Sample IDs for the results of the horizontally or vertically combined integrated data were renamed to include "-Int" at the end of the ID name, and are presented as such in the BHHRA ~~as such~~.

2.2.7 Combining Fillet and Body-~~-~~Without-~~-~~Fillet Tissue Data

Smallmouth bass and carp samples collected during the LWG Round 3 sampling event were analyzed separately as fillet- and body-~~-~~without-~~-~~fillet tissue~~.~~. The results of these analyses were combined on a weighted-average basis to provide whole body results for use in the BHHRA~~.~~. The steps used in combining the data were as follows:

- The whole-body tissue mass was calculated for each individual fish within each composite by summing its fillet- and body-without-fillet tissue mass.
- The ratio of fillet to whole-body tissue mass was calculated for each individual fish within each composite~~.~~. Likewise, the ratio of body-without-fillet to whole-body tissue mass was calculated for each individual fish within each composite.

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- For each composite, the average of the fillet- to whole-body tissue mass ratios was calculated, and the average of body-without-fillet to whole-body tissue mass ratios was calculated to provide an average of the percentage of fillet- and body-without-fillet tissue mass for each composite.

The average percentages were then used to calculate a weighted average ~~of the analytical results~~concentration for each composite sample ~~using~~according to the following rules:

- If the analyte was detected in both the fillet tissue and the body without fillet tissue, a weighted average was calculated using the detected values
- If the analyte was not detected in either of the tissue types, a weighted average was calculated using the full detection limits
- If the analyte was detected either the fillet or body-without-fillet sample, one-half the detection limit for the non-detect result was used to calculate the weighted average.

The combined fillet and body without fillet tissue data were considered whole body tissue results for carp and smallmouth bass and were used in the BHHRA as such.

2.2.8 ~~Summed Analytes and~~ Summation Rules for Analytes Evaluated as Summed Values

Certain ~~Some toxicity values used in the BHHRA were based on exposure to chemical~~contaminants were evaluated as the sum of similar individual ~~mixtures that are~~ congeners, isomers, and ~~or~~ closely related degradation products of ~~a~~the parent compound ~~. As a result, risks were evaluated in the BHHRA based on exposure to the chemical mixture~~ rather than as ~~to the~~ individual ~~components~~chemicals~~.~~. The chemicals evaluated as mixtures and for which analytes ~~were~~evaluated as ~~summed~~sums in the BHHRA ~~include~~are as follows:

- Total PCBs ~~(either as sum of Aroclors or sum of congeners)~~were calculated as either the sum of nine Aroclor mixtures (1016, 1221,1232, 1242, 1248, 1254, 1260, 1262, 1268) or the sum of individual PCB congeners.
- Total endosulfan was calculated as the sum of α-endosulfan, β-endosulfan, and endosulfan sulfate.
- Total chlordane was calculated as the sum of *cis*- and *trans*-chlordane, oxychlordane, and *cis*- and *trans*-nonachlor.
- Total DDD was calculated as the sum of 2,4'-DDD and 4,4'-DDD.
- Total DD~~T~~E was calculated as the sum of 2,4'-DDE and 4,4'-DDE
- Total DD~~E~~T was calculated as the sum of 2,4'-DDT and 4,4'-DDT

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- Total dioxin-like PCB congeners were calculated as the sum of PCBs 77, 81, 105, 114, 123, 126, 156, 157, 167, 169, and 189.
- Total PCBs-adjusted ~~(~~were calculated as the sum of total PCB congeners ~~without~~minus dioxin-like PCB congeners.~~)~~
- ~~Total dioxin-like PCB congeners (calculated to determine value for total PCBs-adjusted)~~
- Total xylenes were calculated as the sum of *m*-, *o*-, and *p*-xylene.

The individual components of each chemical mixture used in the BHHRA are presented in Table F2-2~~–~~.

If an individual analyte of a chemical mixture was detected at least once within the study area in a given medium, it was considered present in that medium~~–~~. ~~For,~~ The presence of an analyte in biota samples was assessed separately for each individual species and tissue~~–~~. The presence of individual analytes in sediment, and surface water were also assessed separately based on the specific exposure scenario~~–~~. Individual analytes that were a part of a chemical mixture but were determined not to be present are summarized in Table F2-3 by medium and species~~–~~. Additionally, a minimum number of individual analytical results in the mixture was required for the summed analytical result to be calculated ~~(regardless of whether the analyte was detected or determined to be present).~~ . For example, if a sample was only analyzed for a limited number of individual PCB congeners, or if a large number of individual congener results for a sample were rejected, a total PCB congener sum may not have been calculated~~–~~. In addition, chemical mixtures for samples meeting the criterion for the minimum number of individual analytical results required to calculate a sum, but with a limited number of individual analytical results, were qualified with an "A."– Mixture sums that did not have a limited number of individual analytical results were qualified with a "T," indicating a calculated total~~.~~ . Table F2-4 shows the minimum number of individual analytical results required to calculate a sum for each mixture, and the maximum number of individual analytical results that would result in an "A" qualifier, indicating a limited number of individual analytical results were available for a sample~~–~~. Table F2-4 also lists the number of samples for each medium for which a summed total was calculated, and the number of samples for which a summed total was not calculated because of lack of individual analytical results for the mixture~~–~~. Sample IDs of samples for which a summed analytical result was not calculated are presented in Table F2-5.

Concentrations of the individual analytes that comprise ~~the~~a mixture~~s~~ were summed for each sample according to the following rules~~, unless otherwise noted~~:

- If an ~~individual~~ analyte was detected in the sample, the detected concentration was used ~~for that chemical in~~to calculate the sum

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- If an ~~individual~~ analyte was not detected in ~~the~~a sample but was ~~determined~~assumed to be present in the sample medium ~~according to the rules in Section 3.1~~, one-half the detection limit was used ~~for that chemical in~~to calculate the sum
- ~~If an individual analyte was determined not to be present in the medium according to the rules in Section 3.1, it was not included in the sum~~
- If ~~none of the individual analytes were detected in the sample~~all results were non-detect, the highest detection limit of the analytes ~~determined~~assumed to be present in the medium ~~according to the rules in Section 3.1~~ was used as the detection limit for the ~~sum~~sample, and the sample was flagged as a non-detect.

~~For surface water, a chemical mixture could result in different summed values for the same sample. This is because these summation rules are based upon the presence of individual analytes in the receptor-specific study area-wide dataset for a given medium, and surface water is the only medium for which subsets of data are different for the different human receptors.~~

~~For some chemical mixtures, a minimum number of individual analytical results in the mixture was required for the summed analytical result to be calculated (regardless of whether the analyte was detected or determined to be present). For example, if a sample was only analyzed for a limited number of individual PCB congeners, or if a large number of individual congener results for a sample were rejected, a total PCB congener sum may not have been calculated. In addition, chemical mixtures for samples meeting the criterion for the minimum number of individual analytical results required to calculate a sum, but with a limited number of individual analytical results, were qualified with an "A." Mixture sums that did not have a limited number of individual analytical results were qualified with a "T," indicating a calculated total. Table F2-4 shows the minimum number of individual analytical results required to calculate a sum for each mixture, and the maximum number of individual analytical results that would result in an "A" qualifier, indicating a limited number of individual analytical results were available for a sample. Table F2-4 also lists the number of samples for each medium for which a summed total was calculated, and the number of samples for which a summed total was not calculated because of lack of individual analytical results for the mixture. Sample IDs of samples for which a summed analytical result was not calculated are presented in Table F2-5. This table shows 85 in-water samples for which Total PCB congeners were not calculated because of limited number of analytical results from the City of Portland outfall sediment investigation. These samples were analyzed for a limited number of congeners that did not meet the minimum number of PCB congeners required to compute a sum. In addition, TEQs were calculated for dioxin and furan congeners and dioxin-like PCB congeners, as discussed in Section 4.0 of this Attachment F2.~~

2.2.9 Total Dioxin/Furan and PCB TEQs

A toxicity equivalence procedure was used to assess the cumulative toxicity of complex mixtures of PCDD, PCDF, and PCB congeners. The procedure involves assigning individual toxicity equivalency factors (TEF's) to the PCDD, PCDF, and PCB congeners in terms of their relative toxicity to 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (2,3,7,8-TCDD)~~. ~~. ~~Toxic Equivalents (TEQs)~~

~~Toxic equivalency factors (TEFs) were used to evaluate risks from dioxin and furan congeners and dioxin-like PCB congeners. C~~The reported concentrations of ~~congeners~~each congener in a sample ~~are~~is multiplied by ~~their~~its respective TEF~~s~~ to ~~estimate~~give the TEF-equivalent ~~toxicity~~concentration~~ of the congeners relative to 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (2,3,7,8-TCDD). ~~. The resulting concentrations are then summed ~~into a~~to give a TEQ~~.~~. The World Health Organization (WHO) TEFs (Van den Berg et al. 2006), shown in Table 4-3, were used to calculate the total dioxin/furan and PCB TEQs~~.~~. Dioxin/furan and PCB-TEQs were calculated according to the following rules~~The following subsections discuss how the TEQs used in the BHHRA were calculated.~~

~~4.1 Total Dioxin/Furan TEQ~~

~~Total dioxin/furan TEQ was calculated by multiplying dioxin and furan congeners by their TEFs, and summing the resulting concentrations. The World Health Organization (WHO) TEFs (Van den Berg et al. 2006), which are shown in Table 4-3 of Appendix F, were used to calculate the total dioxin/furan TEQ. Total dioxin/furan TEQs were calculated according to the following rules:~~

~~For those congeners that were detected, the detected concentration multiplied by the TEF was used in the sum~~

- ~~For those c~~Congeners ~~that were~~reported as not detected in a given sample~~,~~ but determined to be present in the medium ~~according to the rules in Section 3.1~~, ~~½~~one-half the detection limit multiplied by the TEF was used in the sum

~~Congeners that were determined not to be present in the medium according to the rules in Section 3.1 were not included in the sum~~

- If all ~~congeners~~results ~~used to create a TEQ~~in a sample were non-detects, the maximum toxicity-weighted detection limit was used for the TEQ, and the result was flagged as non-detect (U-qualified)~~.~~. The maximum toxicity-weighted detection limit was obtained by multiplying each detection limit by its respective TEF and selecting the maximum value.
- Dioxin/furan TEQs were not calculated for those samples where a~~A~~nalytical results ~~were needed~~ for all 12 dioxin/furan congeners ~~for a TEQ to be calculated, regardless of whether it determined to be present, as indicated in Table F2-4 (i.e., a~~

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~~dioxin/furan TEQ was not calculated for a sample if at least one individual dioxin/furan congener result was rejected, or not analyzed for)~~were not available.

~~4.2 TOTAL PCB TEQ~~

~~Total PCB TEQ was calculated by multiplying coplanar PCB congeners by their TEFs and summing the resulting concentrations. The WHO TEFs, which are shown in Table 4-3 of Appendix F, were used to calculate the total PCB TEQ. The rules for calculating the total PCB TEQ are the same as those used for calculating the total dioxin/furan TEQ.~~

~~4.3 TOTAL TEQ~~

Values were not presented for total TEQ in the BHHRA~~.~~. Rather, risks from total TEQ were estimated by summing the risks from the total PCB TEQ and the total dioxin/furan TEQ.

~~For the purposes of mapping total TEQ concentrations, the values for total PCB TEQ and total dioxin/furan TEQ were summed. If a sample did not have both PCB TEQ and dioxin/furan TEQ values, a total TEQ was not calculated.~~

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2.3 CHEMICAL SCREENING CRITERIA AND SELECTION OF C~~OPC~~ONTAMINANTS OF POTENTIAL CONCERN~~s~~

~~EPA guidance (1989) recommends considering criteria to limit the number of chemicals that are included in a quantitative risk assessment while also ensuring that all contaminants that may contribute significantly to the overall risk are addressed. According to EPA guidance, the screening procedure is used to focus quantitative risk assessment efforts on contaminants that could be of concern under health-protective exposure assumptions. For purposes of the BHHRA, the only screening criterion used to select COPCs was a comparison with risk-based concentrations, a~~~~As described in the Programmatic Work Plan (Integral et al. 2004),~~ Because of the large number of chemicals detected in environmental media, a risk-based screening approach was used to focus the risk assessment on those contaminants most likely to significantly contribute to the overall risk. COPCs were selected for quantitative evaluation in the BHHRA by comparing the SCRA analytical data to risk-based screening values~~).~~. The specific risk-based concentrations used to select COPCs are described below for the ~~respective~~ each media~~BHHRA media.~~. ~~If the maximum detected concentration of a contaminant in a specific media was greater than the screening level, that contaminant was selected as a COPC for beach sediment. When specified below, COPCs were selected for a medium based on a subset of data determined to represent exposure to a specific human population. Potentially exposed human populations are discussed as part of the exposure assessment in Section 3, and include but are not limited to: transients, divers, recreational beach users, and fishers.~~

2.3.1 Sediment

~~2.3.1 Sediment~~

~~Sediment data were quantitatively evaluated in the BHHRA for direct exposure scenarios. As a health-protective initial approach, the current~~ EPA's Regional Screening Levels (RSLs) for soil (EPA 2010a) were used as the ~~basis for~~ screening values for beach and in-water sediments~~.~~. RSLs are risk-based concentrations in soil, air and water, and have been developed for both residential and industrial exposure scenarios~~.~~. Using default exposure assumptions, RSLs represent concentrations that equate to a target cancer risk of 1×10^{-6} or a hazard quotient of 1~~.~~. As described in Region 10 guidance (2007a), RSLs based on a noncancer endpoint were divided by 10 to give a value equivalent to using a

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hazard quotient of 0.1~~—~~. This was done to account for the additive nature of noncancer effects~~—~~. RSLs based on ~~For noncarcinogenic chemicals, the EPA RSLs~~noncancer endpoints were divided by 10 to account for potential cumulative effects from multiple chemicals, and these modified RSLs were used as the screening values~~—~~. ~~For chemicals that exhibit both carcinogenic and noncarcinogenic effects, the lower screening value was used for selecting COPCs.~~ Consistent with the then current EPA Region- 10 ~~guidance~~recommendations (EPA, 2008), a RSL of 7.7- mg/kg in soil for residential land use was calculated for trichloroethylene (TCE) using a cancer slope factor of 0.089 per mg/kg--day, ~~representing~~which represents the geometric mid-point of the slope factor range from EPA 2001~~—~~. EPA finalized its risk assessment for TCE in 2011 and the revised RSL is 0.9 mg/kg. Because TCE does not contribute substantially to the cumulative risk estimates for the in-water portion of Portland Harbor, the screening process was not re-evaluated. Chemicals for which no RSL was available were screened using RSLs for~~Surrogate~~ chemicals with a similar chemical structures~~, RSLs for were used if available (e.g., pyrene was used as a surrogate for phenanthrene) for chemicals without RSLs. ~~.

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~~Dividing EPA RSLs for noncarcinogenic chemicals by 10 is Because the potential exposure to sediments that may occur is anticipated to be less than the exposure that was assumed to occur with soil in developing the EPA RSLs, the soil RSLs represent conservative screening values for protection of human health.~~ Because uses of Portland Harbor include both recreational and industrial activities, COPCs were selected using both residential and industrial ~~EPA~~ RSLs, consistent with the EPA comments on the Round 2 Comprehensive Report ~~provided on January 15, 2008~~ (EPA- 2008b).~~. For chemicals that do not have EPA RSLs, EPA RSLs for surrogate chemicals with similar chemical structures were used if available (e.g., pyrene for was used as a surrogate for phenanthrene). As required by EPA Region 10 (see e-mail from Dana Davoli to Laura Kennedy, October 17, 2008, in Attachment F1), for trichloroethylene, the geometric mid-point of the slope factor range from EPA 2001 (0.089 per mg/kg-day) was used for evaluating cancer risks for both inhalation and oral exposures. This value was also used to calculate an acceptable soil screening level of 7.7 mg/kg.~~
Residential

~~For carcinogenic chemicals, the EPA RSLs were used as the screening values. For noncarcinogenic chemicals, the EPA RSLs were divided by 10 to account for potential cumulative effects from multiple chemicals, as required by EPA Region 10 (2007a), and these modified RSLs were used as the screening values. For chemicals that exhibit both carcinogenic and noncarcinogenic effects, the lower screening value was used for selecting COPCs.~~

~~EPA RSLs have been developed for both residential and industrial exposure scenarios for soil. Residential soil EPA RSLs are based on exposure assumptions of 350 days per year. For cancer endpoints, the residential EPA RSLs are calculated using an age-adjusted soil ingestion factor that takes into account the difference in daily soil ingestion rates, body weight, and exposure duration for children from 1 to 6 years old and others from 7 to 31 years old (total exposure over 30 years). For noncancer endpoints, the residential EPA RSLs are calculated using exposure factors for children from 1 to 6 years old and chronic toxicity criteria. Industrial soil EPA RSLs are based on exposure assumptions of 250 days per year for 25 years. Both residential and industrial EPA RSLs are based on a target cancer risk of 1 x x 10^{-6} for carcinogenic chemicals or a hazard quotient of 1 for noncarcinogenic chemicals. Dividing EPA RSLs for noncarcinogenic chemicals by 10 is equivalent to using a hazard quotient of 0.1. Because the potential exposure to sediments that may occur is anticipated to be less than the exposure that was assumed to occur with soil in developing the EPA RSLs, the soil RSLs represent conservative screening values for protection of human health. Because uses of Portland Harbor include both recreational and industrial activities, COPCs were selected using both residential and industrial EPA RSLs, consistent with the EPA comments on the Round 2 Comprehensive Report provided on January 15, 2008 (EPA 2008b).~~

~~For beach sediment, residential soil EPA~~ RSLs were used to select COPCs ~~in~~ ~~for~~in beach sediment ~~in~~for those areas where exposures could occur during recreational, transient, or fishing activities~~. Only~~ in those areas considered reasonably accessible~~, such as those with access~~ from contiguous upland areas or by boat~~.~~. In-water sediment data collected within the navigation channel were not used in the COPC screen~~.~~. ~~were evaluated as~~ In areas where occupational exposures could occur, and for in-water sediment,~~,~~ COPCs were selected using industrial ~~soil EPA~~ RSLs~~.~~.

If the maximum detected concentration of a contaminant at a specific use area was greater than its respective screening level, that contaminant was selected as a COPC~~.~~. The designated potential uses for beaches in the Study Area are presented in ~~Map~~ Map 2-~~-~~1~~.~~. ~~The contaminants selected as~~ COPCs ~~for~~for beach ~~beach~~ sediment and the rationale for selection are presented in Tables- 2-9 and 2-10~~,~~. COPCs for in-water sediment are presented in Table 2-11.

~~Groundwater Seep~~

~~Chemicals concentrations detected in the groundwater seep at Outfall 22B were compared to the residential tapwater RSLs. . As with the soil RSLs, the tapwater RSLs based on a noncancer endpoint were divided by 10 to give values equivalent to a HQ of 0.1. . The location of Outfall 22B is shown on Map 2-5, and COPCs are presented in Table 2-15.~~

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~~The extent of direct contact (i.e., ingestion and dermal contact) with in-water sediment that could occur under site-specific exposure scenarios would be significantly less than with upland soil or beach sediment. Therefore, COPCs for in-water sediment were identified using only the industrial soil EPA RSLs.~~

2.3.2 Surface Water ~~and Groundwater Seeps~~

Screening values for surface water and groundwater seeps ~~Surface water and groundwater seep data were quantitatively evaluated in the BHHRA for direct exposure scenarios. A discussion of potential sources of contaminants to surface water is provided in the RI. As a health-protective initial approach,~~ EPA residential tapwater RSLs ~~for residential tapwater~~ (EPA 2010a) and MCLs (EPA 2003a) were generally used as ~~the~~ screening values for surface water and the groundwater seep to select COPCs for direct exposure scenarios. ~~For chemicals that do not have EPA RSLs, EPA RSLs for surrogate chemicals with similar chemical structures were used if available (e.g., pyrene for phenanthrene). As required by EPA Region 10 (EPA 2007a),~~ TCE was evaluated using the~~the~~ EPA Region 6 Human Health Medium-Specific Screening Levels ~~for trichloroethylene~~ (EPA 2008a)~~, rather than the EPA RSLs, were used in this BHHRA.~~. ~~For carcinogenic chemicals, the EPA RSLs were used as the screening values. For noncarcinogenic chemicals, the EPA RSL was divided by 10 to account for potential cumulative effects from multiple chemicals, and this modified EPA RSL was used as the screening value, as required by EPA Region 10.As with the soil RSLs, screening levelsthe tapwater RSLs based on a noncancer endpoint were divided by 10 to give values equivalent to a HQ of 0.1.~~

COPCs were selected separately for divers~~and~~, transient/beach user exposures, and the potential use of surface water as a ~~drinkinghousehold~~drinking— water source. COPCs for evaluating exposure ~~by~~to divers and for drinking water were selected from ~~all available surface water samples taken within the Study Area~~the combined surface water data set described in Section 2.2.6. ~~Near-bottom and near-surface sample results, as well as vertically integrated transect results, were combined according to the rules described in Attachment F2 prior to selecting COPCs. For transients and beach users,~~ COPCs for transient and beach use scenarios were selected from surface water samples taken from areas where direct contact ~~with transient or beach users~~ could occur.~~, including both single point sampling stations where vertically integrated samples were collected and transect samples. This included one sample from Swan Island Lagoon.~~ A summary of samples used for screening surface water for COPCs is provided in Table 2-12. Sample locations of surface water data evaluated and COPCs for diver exposures are shown on Map 2-3 and in Table 2-13; sample locations and COPCs for transient and recreational beach uses~~, diver exposures,~~ are shown on Map 2-4 and Table 2-14; sample locations and COPCs for ~~household~~the use of surface water as a drinking water source are shown on ~~Map 2-3, 2-4, and~~ Map 2-8~~, respectively~~ and in Table 2-16. ~~Surface water data gathered during the RI were used to identify the COPCs for quantitative evaluation in the BHHRA. At the direction of EPA, results from surface water samples collected near-bottom and near-~~

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~~surface within the water column were combined according to the rules described in Attachment F2. The combined near-bottom and near-surface samples, vertically integrated single point samples, and vertically integrated transect samples were used to select the COPCs. These samples are presented in Table 2-12, and shown in Map 2-8. Filter and column data collected from samples collected by XAD were combined before selection of COPCs, according to the rules described in Attachment F2Section 2.2.5. The contaminants selected as COPCs for surface water as a drinking water source, and the rationale for selection, are presented in Table 2-16.~~

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2.3.3 Groundwater Seep

Chemicals concentrations detected in the groundwater seep at Outfall 22B were compared to the residential tapwater RSLs. As with the soil RSLs, the tapwater RSLs based on a noncancer endpoint were divided by 10 to give values equivalent to a HQ of 0.1. The location of Outfall 22B is shown on Map 2-5, and COPCs are presented in Table 2-15.

~~No further data reduction was performed on the hypothetical future domestic water dataset prior to COPC selection.~~

~~For chemicals that were detected in this dataset, the detected concentrations were compared to screening values based on the RSLs for tap water and on EPA MCLs for drinking water (EPA 2003a). If the maximum detected concentration of a contaminant in surface water was greater than either of the screening values, that contaminant was selected as a COPC for surface water and was quantitatively evaluated in the BHHRA.A summary of samples used for for each surface water COPC screening surface water for COPCs is provided in Table 2-12. SIn addition, the sample locations of the surface water data evaluated for transients and recreational beach uses r exposure scenarios are shown in Map 2-3., The sample locations of the surface water data evaluated for diver exposures are shown in Map 2-4.~~

~~Fish and Shellfish Residential tapwater EPA RSLs are based on domestic use of water, including ingestion, and represent conservative screening values for direct contact scenarios where water may not be used for domestic purposes, such as surface water contact during beach recreation. EPA RSLs are based on a target cancer risk of 1 x x 10^-6 for carcinogenic chemicals or a hazard quotient of 1 for noncarcinogenic chemicals. Dividing EPA RSLs for noncarcinogenic chemicals by 10 is equivalent to using a hazard quotient of 0.1.~~

~~2.3.3 Tissue~~

~~EPA Region 10 has not accepted any risk-based screening criteria for screening tissue from Portland Harbor; therefore, per an agreement with EPA, risk-based concentrations were not used for screening the tissue data,. Aand all chemicals~~

~~detected in fish and shellfish in the BHHRA dataset were selected as COPCs for tissue.~~

~~2.3.4 Hypothetical Future Exposure to Untreated Surface Water for Domestic Use~~

~~Even though no current or future uses of the LWR within Portland Harbor as a domestic water source have been identified, under OAR 340-041-0340 Table 340A, domestic water supply is a designated beneficial use of the Willamette River, with adequate pretreatment. Because the Willamette River is capable of serving as a potential drinking water source, the expectation is that this resource will be protected to achieve such use with adequate pretreatment. Although surface water within the Study Area is not currently used as a domestic water source, nor are there future plans for domestic water use within the Study Area, surface water data were quantitatively evaluated in the BHHRA as a hypothetical future domestic water source at the direction of EPA (see Section 2.4.5 below). The same criteria and screening values used for data to assess direct contact with surface water and the groundwater seep were used to select COPCs for surface water as a hypothetical future domestic water source. As with the surface water and groundwater seep screening, the noncarcinogen RSLs were divided by 10 to account for potential multiplicative effects, and the modified RSLs were used as the screening values.~~

~~In addition to the EPA RSLs, EPAEPA residential tapwater RSLs (EPA 2010a) and maximum contaminant levels (MCLs) for drinking water (EPA 2003a) were used as screening criteria for the selection of COPCs for the hypothetical future use of untreated surface water for for drinking waterdomestic purposes. If the maximum detected concentration for of a contaminant in the dataset selected to represent hypothetical exposure to untreated surface water for domestic use exceeded either the EPA RSL or the EPA MCL, the contaminant was selected as a COPC for this scenario.~~

~~2.4 IDENTIFICATION OF CONTAMINANTS OF POTENTIAL CONCERN~~

~~As described in the Programmatic Work Plan (Integral et al. 2004), COPCs were selected for quantitative evaluation in the BHHRA by comparing the SCRA analytical data to risk-based screening values. The specific risk-based concentrations used to select COPCs are described below for the each media. COPCs for human health were selected according to the approach described in the Programmatic Work Plan (Integral et al. 2004) using the screening criteria described in Section 2.3 and were quantitatively evaluated in this BHHRA. The process used to select the COPCs for quantitative evaluation in this BHHRA is described in the following subsections.~~

~~2.4.1 Sediment~~

~~Humans can be exposed to both beach sediment and in-water sediment. Because the exposure scenarios for beach versus in-water sediment are different, COPCs were selected for both beach and in-water sediment exposures.~~

~~2.4.1.1 Beach Sediment~~

~~Beach sediment data were evaluated in the BHHRA for potential risks to human health through direct contact. The selection of COPCs for beach sediment evaluated sediment data from potential human use areas where direct contact with human receptors could occur (only reasonably accessible beach sediments, such as those with access from contiguous upland areas or by boat). The locations of the beach sediment data evaluated in the BHHRA are shown in Map 2-1.~~

~~For contaminants that were detected in beach sediment, the detected concentrations were compared to risk-based screening levels described in Section 2.3.1. The maximum detected concentration of each contaminant from all samples collected in recreational, transient, or fishing beach areas was compared to the screening level based on the residential soil EPA RSL. The maximum detected concentration of each contaminant from all samples collected in industrial beach areas was compared to the screening level based on the industrial soil EPA RSL. If the maximum detected concentration of a contaminant was greater than the screening level, that contaminant was selected as a COPC for beach sediment. The contaminants selected as COPCs for beach sediment and the rationale for selection are presented in Tables 2-~~~~-9 and 2-~~~~-10.~~

~~Contaminants selected as COPCs for beach sediment were quantitatively evaluated in this BHHRA. Contaminants with maximum detected concentrations less than the screening values were not selected as COPCs and were not evaluated further in this BHHRA for direct contact with beach sediment.~~

~~2.4.1.2 In-Water Sediment~~

~~In-water sediment data were evaluated in the BHHRA for potential risks to human health through direct contact and not basedrather than on the potential for bioaccumulation. The potential for bioaccumulation, which is evaluated separately in this BHHRA as part of the fish and shellfish tissue assessments. The selection of COPCs for in-water sediment evaluated all surface sediment data in the BHHRA dataset within the Study Area, excluding the navigation channel and beach composite samples. The sample locations of the in-water sediment data evaluated in the BHHRA are shown in on Map~~
~~2-2.~~

~~For chemicals that were detected in in-water sediment, the maximum detected concentration of each chemical from surface sediment samples was compared to the screening level based on the EPA industrial soil EPA RSL, as described in Section~~

~~2.3.1. If the maximum detected concentration of a contaminant was greater than the screening level, that chemical was selected as a COPC for in-water sediment. The contaminants selected as COPCs for in-water sediment and the rationale for selection are presented in Table 2-11.~~

~~Contaminants selected as COPCs for in-water sediment were quantitatively evaluated in this BHHRA. Chemicals with maximum detected concentrations less than the EPA RSLs were not selected as COPCs and were not evaluated further in this BHHRA for direct contact with in-water sediment.~~

~~2.4.2 Surface Water~~

~~Direct contact with surface water was evaluated in the BHHRA for potential risks to human health. The selection of COPCs for quantitative evaluation in the BHHRA in surface water was based only on potential for direct human contact and not based on the potential for bioaccumulation. The potential for bioaccumulation is evaluated separately in this BHHRA as part of the fish and shellfish tissue assessments. Surface water data gathered during the RI were used to identify the COPCs in surface water for quantitative evaluation in the BHHRA. Because the exposure scenarios for divers are different from those of transients and beach users, COPCs were selected separately for both divers and transient/beach user exposuresscenarios. For divers, COPCs were selected for divers from using all available surface water samples taken within the Study Area, as described in Section 2.1.3. Near-bottom and near-surface sample results, as well as vertically integrated transect results, were combined according to the rules described in Attachment F2 prior to selecting COPCs. For transients and beach users, COPCs were selected for transients and beach users from surface water samples taken from areas where direct contact with transient or beach users could occur, including both single point sampling stations where vertically integrated samples were collected and transect samples were collected. This included, as well as one sample from Swan Island Lagoon. Chemicals that were detected in each surface water dataset, the detected concentrations were compared to screening values based on the residential tapwater RSLs. If the maximum detected concentration of a contaminant in surface water was greater than the screening value, that contaminant was selected as a COPC for surface water and was quantitatively evaluated in the BHHRA. A summary of samples used for each surface water COPC screening is provided in Table 2-12. SIn addition, the sample locations of the surface water data evaluated for transients and recreational beach users exposure scenarios are shown in on Map 2-3. The, and sample locations of the surface water data evaluated for divers exposures are shown in on Map Map 2- 4.~~

~~For chemicals that were detected in each surface water dataset, the detected concentrations were compared to screening values based on the residential tapwater RSLs. If the maximum detected concentration of a contaminant in surface water was greater than the screening value, that contaminant was selected as a COPC for surface water and was quantitatively evaluated in the BHHRA. Chemicals that were detected~~

~~only at concentrations less than the RSLs were not selected as COPCs for quantitative evaluation. The contaminants selected as COPCs for surface water and the rationale for selection are presented in Table 2-13 for divers, and Table 2-14 for transients and beach users.~~

~~2.4.3 Groundwater Seep~~

~~Direct contact with the groundwater seep at Outfall 22B, shown in Map 2-5, was evaluated in the BHHRA for potential risks to human health. The selection of COPCs for quantitative evaluation in the BHHRA was based only on potential for direct human contact with the groundwater seep, and not based on the potential for bioaccumulation.~~

~~For chemicals that were detected in the groundwater seep, the detected concentrations were compared to screening values based on the residential tapwater EPA RSLs. If the maximum detected concentration of a contaminant in the groundwater seep was greater than the screening value, that contaminant was selected as a COPC for the groundwater seep and was quantitatively evaluated in the BHHRA. Chemicals that were detected only at concentrations less than the EPA RSLs were not selected as COPCs for quantitative evaluation. The contaminants selected as COPCs for the groundwater seep and the rationale for selection are presented in Table 2-15.~~

~~2.4.4~~2.3.4 Fish and Shellfish Tissue

No appropriate risk-based screening values for fish tissue were available. Although EPA Region 3 has published fish tissue screening levels, the consumption rate of 54 g/day used to derive those values is not considered representative of the range of consumption rates relevant to Portland Harbor. ~~Fish and shellfish tissue were evaluated in the BHHRA for potential risks to human health through ingestion. Because EPA Region 10 has not accepted any criteria for screening tissue from Portland Harbor~~Accordingly, all chemicals detected in fish and shellfish tissue in the BHHRA dataset were considered to be COPCs and evaluated further in the BHHRA~~.~~. ~~Map 2-6 shows~~ T~~t~~he general locations of ~~all fish~~ fish in a ~~for a~~ particular composite of ~~the~~ smallmouth bass and common carp ~~tissue data~~are shown on -Map- 2--6~~evaluated for ingestion scenarios in this BHHRA.~~ . B~~Samples for b~~rown bullhead and black crappie were ~~each~~ composited ~~for~~ over ~~RM~~ RM 3-6 and ~~RM~~ RM 6-9~~, and are not shown on a map.~~ . ~~The sample locations of the shellfish tissue data (both crayfish and clam) evaluated for ingestion scenarios are shown in Map 2-7.~~ Shellfish were ~~also~~ composited over areas representing their assumed home range, and ~~the~~ sample locations on ~~Map~~ Map 2-7 represent the general spatial distribution of composited samples~~.~~.

~~The contaminants detected in each individual species were selected as COPCs only for ingestion of that species. For the multi-species diet scenarios (discussed in Section 3), analytes detected in any of the target resident fish species (see Section~~

~~2.1.5) were selected as COPCs. Since no screening took place to determine COPCs for tissue, the tissue COPCs are presented in the exposure point concentration summary tables, discussed in Section 3.~~

~~2.4.5 Hypothetical Future Exposure to Untreated Surface Water for Domestic Use~~

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~~There is no known current or anticipated future use of surface water within the Study Area for a drinking water supply. Even though no current or future uses of the LWR within Portland Harbor as a domestic water source have been identified, under OAR 340-041-0340 Table 340A, domestic water supply is a designated beneficial use of the Willamette River, with adequate pretreatment. Because the Willamette River is capable of serving as a potential drinking water source, the expectation is that this resource will be protected to achieve such use with adequate pretreatment. Potential sSources of contaminants to surface water are discussed in the RI. Because future use of the LWR as a domestic water supply would require adequate pretreatment, the evaluation of untreated surface water as a drinking water source is designated a hypothetical scenario. The inclusion of the assessment of domestic use of untreated surface water from the Study Area was done at the direction of EPA.~~

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~~Surface water as a hypothetical future domestic water source was evaluated in the BHHRA for potential risks to human health. The selection of COPCs for quantitative evaluation in the BHHRA in surface water was based only on potential for hypothetical contact from domestic uses, and not based on the potential for bioaccumulation. The potential for bioaccumulation is evaluated separately in this BHHRA as part of the fish and shellfish tissue assessments. Surface water data gathered during the RI were used to identify the COPCs for quantitative evaluation in the BHHRA. At the direction of EPA, results from surface water samples collected near-bottom and near-surface within the water column were combined according to the rules described in Attachment F2. The combined near-bottom and near-surface samples, vertically integrated single point samples, and vertically integrated transect samples were used to select the COPCs. These samples are presented in Table 2-12, and shown in Map 2-8. Filter and column data collected from samples collected by XAD were combined before selection of COPCs, according to the rules described in Attachment F2. No further data reduction was performed on the hypothetical future domestic water dataset prior to COPC selection.~~

~~For chemicals that were detected in this dataset, the detected concentrations were compared to screening values based on the RSLs for tap water and on EPA MCLs for drinking water (EPA 2003a). If the maximum detected concentration of a contaminant in surface water was greater than either of the screening values, that contaminant was selected as a COPC for surface water and was quantitatively evaluated in the BHHRA. Chemicals that were detected only atfor which the maximum detected concentrations concentration was less than both screening values were not selected as COPCs for quantitative evaluation. The maximum detected concentration did not exceed the MCL for any chemical (Table 2-16). Maximum concentrations exceeded other RSLs [e.g., tap water screening levels for arsenic and 2-(4-Chlorochloro-2-methylphenoxy)propanoic acid (MCPP)]. The contaminants selected as~~

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~~COPCs for surface water as a hypothetical domestic water source, and the rationale for selection, are presented in Table 2-16.~~

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3.0 EXPOSURE ASSESSMENT

Exposure assessment is the determination of the magnitude, frequency, duration, and route of exposure (EPA, 1989)~~–~~. Populations that currently, or may in the future, come into contact with site contaminants are identified along with potential routes of exposure that define the mechanism by which the exposure may occur~~–~~. Magnitude is determined by estimating the amount, or concentration, of the chemical at the point of contact over an exposure duration, as well as the actual intake, or dose, of the chemical. ~~The objectives of the exposure assessment are to identify potential exposure pathways for individuals who may come in contact with COPCs at the Study Area, to characterize potentially exposed populations, and to estimate the extent of exposure.~~

~~The exposure assessment in this BHHRA followed EPA guidance and incorporated the reasonable maximum exposure (RME) methods recommended by EPA. As stated in EPA guidance (EPA 1989), the RME is a conservative exposure level that is still within the range of possible exposures. The exposure assessment also used average values, which represent central tendency (CT) exposures, for some exposure scenarios.~~ According to EPA (1989), an exposure assessment includes ~~four~~ three primary tasks:

- ~~Identify potentially exposed human populations that may come in contact with the COPC. This requires knowledge of (and/or making reasonable assumptions regarding) both current and future populations.~~Characterization of the exposure setting~~–~~. This step includes identifying the characteristics of populations that can influence their potential for exposure, including their location and activity patterns, current and future land use considerations, and the possible presence of any sensitive subpopulations~~–~~.
- ~~Identify~~ Identification of ~~relevant~~ exposure pathways~~–~~. Exposure pathways are identified for ~~human~~ each population~~s~~ by which ~~potentially exposed populations may contact environmental media containing COPCs~~they may be exposed to chemicals originating from the site.
- Quantification of exposure~~–~~. The magnitude, frequency, and duration of exposure for each pathway is determined~~–~~. This step consists of the estimating of exposure point concentrations and calculation of chemical intakes~~–~~. ~~Estimate EPCs at the points of potential human contact for all identified COPCs.~~
- ~~Estimate daily intakes for exposure routes and potentially exposed populations. The daily intakes are derived using the EPCs and assumptions regarding such variables as exposure duration, consumption rates, skin absorption factors, and other parameters that describe human activities.~~

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~~As stated in EPA guidance (EPA 1989), actions at Superfund sites should be based on an estimate of the reasonable maximum exposure (RME) expected to occur under both current and future land use conditions. Tthe RME is a conservative~~

~~exposuredefined as the highest exposure that is reasonably expected to occur at a site. The intent is to estimated a conservative exposure level that is substantially greater than the average, yet is still within the range of possible exposures. Theis BHHRA also exposure assessment also used average values, which representevaluated central tendency (CT) exposures, which is intended to represent the average exposure experienced by the affected population,. for some exposure scenarios. The exposure assumptions and methods for each task included in the exposure assessment are discussed below.~~

3.1.1 Conceptual Site Model

The conceptual site model (CSM) describes potential contaminant sources, transport mechanisms, potentially exposed populations, exposures pathways and routes of exposure~~.~~. As discussed in Sections 4, 5, and 6 of the RI Report, contaminated media within the Study Area are sediment, water, and biota~~.~~. Current and historical industrial activities and processes within the Study Area have led to chemical releases from either point or nonpoint sources, including discharges to the river from direct releases or via outfalls and groundwater within the Study Area~~.~~. In addition, releases that occur upstream of the Study Area and atmospheric deposition from global, regional, and local emissions may also represent potential contaminant sources to the Study Area~~.~~. Chemicals in sediment and water may be accumulated by organisms living in the water column or ~~associated~~by benthic organisms in ~~with the~~ sediments~~.~~. Fish and shellfish within the Study Area feeding on these organisms can accumulate chemicals in their tissues through dietary and direct exposure to sediment and water~~.~~. Additional information on potential contaminant sources is provided in Section ~~5~~4 of the RI Report, and a more detailed CSM is presented in Section 10~~.~~. A graphical representation of the exposure CSM ~~Potentially complete exposure pathways were identified in the Programmatic Work Plan or based on subsequent requirements from EPA. In-water workers exposure to river sediment, transients exposure to shoreline seeps, divers exposure to surface water and in-water sediment, infant exposure via consumption of human milk for all receptors with bioaccumulative COPCs, and hypothetical future exposures of domestic water users to surface water were included as potentially complete pathways per requirements from EPA. Pathways that are potentially or hypothetically complete and may result in significant exposure, or for which significance is unknown, were evaluated quantitatively in this BHHRA, per direction from EPA. Pathways included at the direction of EPA include clam consumption, exposure to surface water and in-water sediment by a commercial diver, and hypothetical exposure to untreated surface water by a domestic water user.~~ is presented ~~i~~on Figure 3-1.

~~3.1~~3.2 IDENTIFICATION OF POTENTIALLY EXPOSED HUMAN POPULATIONS

Potentially exposed ~~and hypothetically exposed~~ populations were identified based on consideration of current ~~, future, and hypothetical~~and potential future uses of the Study Area ~~and EPA (1989) guidance.~~. An analysis of potential exposure pathways ~~analysis~~ for the Study Area is detailed in the Portland Harbor RI/FS Programmatic Work Plan (Integral 2004)~~.~~. The ~~human populations~~exposure scenarios identified below represent those populations that are anticipated to ~~be maximally exposed~~ have the greatest potential for exposure to contaminants within the Study Area for both ~~under~~ current and ~~reasonably foreseeable~~potential ~~or hypothetical~~ future conditions~~.~~. ~~The~~ For this reason, this risk assessment ~~evaluation performed for the selected populations~~ is ~~considered~~ likely to be protective of ~~certain~~ other potentially exposed populations that are not evaluated quantitatively in this BHHRA~~.~~. The ~~populations~~ receptors evaluated for current~~, future, and hypothetical~~ and future uses of the Study Area ~~include~~ are~~the following~~:

- Dockside workers
- In-water workers
- Transients
- Divers
- Recreational beach users
- ~~Non-tribal~~Recreational/Subsistence Fishers
- Tribal fishers
- Domestic water users
- ~~These receptors above populations were identified based on human activities that are known to occur within the Study Area, as described in the Programmatic Work Plan, or were required directed by EPA for evaluation in this BHHRA. The receptors and exposure pathways evaluated at the direction of EPA are Diversdivers, clam consumption by fishers, and household uses of surface waterdomestic water user were included in this BHHRA as required by EPA., and exposure to bioaccumulativepersistent organic chemicals (PCBs, dioxin/furans, DDx, and PDBEs) via Infant consumption of human milk by infantswas included as a complete exposure pathway for all adult receptor populations that were assessed quantitatively for bioaccumulative chemicals (i.e., PCBs, dioxin/furans, and DDX), as required by EPA.~~

~~Potential Estimated risks were quantified for each of theidentified receptor population.s; however However, certain individuals may participate in activities resulting in potential exposures under more than one category (e.g., recreational~~

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~~beach users may also be fishers). Potentially overlapping exposures are discussed in Section 3.3.7 of this BHHRA.~~

~~This BHHRA focused on potential exposures occurring within and immediately upstream and downstream of the Study Area in quantifying potential risks to humans.~~

~~ExceptWith the exception for the hypotheticalof the future exposure to use of untreated surface water for as a domestic water userssource, the exposure assessment assumes that future land and water use will be the same as current land use; therefore, the risks characterized are based only on current use.these receptors evaluated in the risk assessment are known to currently exist based on the current land use and activity patterns in the Study Area. .~~The above populations were identified based on human activities know to occur within the Study Area, with the exception the use of surface water as a domestic water source. However, public and private use of surface water is a beneficial use of the LWR, and as described in Section 1, this baseline risk assessment evaluates exposures assuming no institutional controls, such as obtaining a permit for use of surface water. ~~If land or water use changes in the future, exposures and risk estimates may also change.~~Each of these receptors is described in greater detail in the following sections.

3.2.1.1 Dockside Workers

Portland Harbor supports a large number of water-dependent commercial uses, and many of the facilities adjacent to the LWR rely on ship and barge traffic~~—~~. Dockside workers ~~include~~were evaluated to be representative of industrial and commercial workers at many of the facilities adjacent to the river~~—~~. -S~~who conduct~~ specific activities are assumed to occur only within natural river beach areas, and include ~~, such as~~ unloading ships or barges~~ from the beach itself~~, or conducting occasional maintenance activities ~~from~~at specific locations near or at the water's edge~~. The actual activities that occur within natural river beach areas are site-specific and generally occur only infrequently. . Although exposure is anticipated to be infrequent, workers conducting activities within natural river beach areas may contact beach sediment within riverfront industrial and commercial sites atwithin the Study Area.~~ Exposures for ~~a given worker would~~ dockside workers are evaluated ~~in the risk assessment individually~~ as ~~occur~~occurring only within ~~the~~ defined ~~dockside worker use~~ areas considered to be industrial sites, rather than on a Study Area or harbor-wide basis~~ adjacent to the facility of that worker. . Exposure frequency for the RME evaluation was assumed to be 200 days/year, which is somewhat less than a typical occupational frequency of 250 days/year (five days/week for 50 weeks/year). The CT evaluation assumed an exposure frequency of 50 days/year. Dockside workers could potentially be exposed to beach sediment in areas~~The specific areas evaluated ~~considered to be industrial sites as~~are shown on Map- 2-1~~, and beach sediment data from each of these areas were used to estimate the EPCs. . If the beach area extends across multiple industrial sites, the same EPC was used to evaluate exposure at each of the adjacent sites. EPCs in beach sediment for the dockside worker scenario are presented in Table 3-2.~~

3.2.1.2 In-Water Workers

~~While I~~this population is referred to as “in-water” workers, these workers are not actually in the water. Rather, ~~i~~In-water workers ~~are~~were evaluated as representative of individuals ~~those workers~~ who conduct activities that typically occur in or over-water ~~activities such as maintenance dredging andor repair of in-water structures~~, rather than on shore as assumed for dockside workers. ~~.~~ Specific activities may include the repair of in-water structures such as docks or pilings, ~~Exposure to in-water sediment could occur anywhere within the Study Area that docks or pilings are being constructed, or where other in-water activities occur, such as~~ maintenance dredging of private slips or berths, or~~.~~ ~~while performing these specific activities, although most maintenance dredging activities are mechanical and are unlikely to result in significant sediment contact. Although likely occurring less frequently than mechanical dredging activities, other activities such as~~ maintenance and cleaning of equipment ~~may also result in direct contact exposure to in-water sediments.~~ . While ~~these~~such activities would not necessarily be restricted to a given area, exposure would most likely be localized to ~~in-water sediment at~~ specific facilities, and between the shore and the navigation channel.~~or in off-loading sediments to disposal sites may result in a greater exposure potential.~~

3.2.1.3 Divers

Several different groups of people ~~Diving is done by~~dive ~~several groups of people~~ in the Portland Harbor area, including the public for recreation and gathering of biota for consumption, the sheriff’s office for investigations and emergency activities, and commercial divers for a variety of purposes including marine construction, underwater inspections, routine operation and maintenance, and activities related to environmental work~~.~~. The majority of divers are expected to be commercial divers who typically use either wet or dry suits, wet or dry gloves, and a full face mask or a regulator held in the mouth with the diver's teeth~~.~~. Although dry suits provide greater protection, wetsuits are often used because of the higher cost of dry suits and water temperature~~.~~. The Willamette River is 303d listed as a temperature impacted area, with the Lower Willamette reaching average temperatures of over 70 degrees F in the summer months~~.~~. Based on communications with commercial diving companies in the Portland area (Hutton 2008, Johns 2008, and Burch 2008), the standard of practice for commercial divers is the use of dry suits and helmets when diving in the LWR~~.~~. However, ~~EPA has noted that~~ the use of wet suits is apparently still common among many commercial divers (EPA 2008c)~~.~~. Accordingly, two different diver exposure scenarios are included in this BHHRA, and are differentiated by considering the use of either a wet suit or dry suit~~.~~. Each scenario assumes that divers are exposed to sediment and surface water through inadvertent ingestion and dermal contact~~.~~ throughout the Study Area. ~~. TIn the Study Area, the majority of divers are expected~~

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~~to be commercial divers. To evaluate diver exposures, two different exposure scenarios are included in this BHHRA, one assuming that a wet suit is worn during diving and one assuming that a dry suit is worn during diving. The diver exposure scenarios were directed by EPA in a memorandum regarding the *Proposed Commercial Diver Exposure Scenario for the Portland Harbor Risk Assessment* (EPA 2008c). Both the wet suit and dry suit diver exposure scenarios assume that the diver is exposed to sediment through inadvertent ingestion of sediment and dermal exposure to sedimentcontact. As EPA stated in its approach, the use of a dry suit is expected to limit diver exposure, so it is assumed that the wet suit diver has more dermal exposure to sediment than the dry suit diver. Based on communications with commercial diving companies in the Portland area (Hutton 2008, Johns 2008, and Burch 2008), the standard of practice for commercial divers is the use of dry suits and helmets when diving in the LWR. However, based on the directive of the EPA, the wet suit diver scenario is also included in this BHHRA.wo different diver exposure scenarios are included in this BHHRA, and are differentiated by considering the use of either a wet suit or dry suit. Both scenarios assume that the diver is exposed to surface water through inadvertent ingestion of dermal contact. The use of a dry suit is expected to limit diver exposure, so a diver using a wet suit is assumed to have greater potential for dermal exposure to surface water. The majority of divers in the Study Area are expected to be commercial divers. The diver exposure scenarios were directed by EPA in a memorandum regarding the *Proposed Commercial Diver Exposure Scenario for the Portland Harbor Risk Assessment* (EPA 2008c). Both the wet suit and dry suit diver exposure scenarios assume that the diver is exposed to sediment through inadvertent ingestion and dermal contact. As EPA stated in its approach, the use of a dry suit is expected to limit diver exposure, so it is assumed that the wet suit diver has more dermal exposure to sediment than the dry suit diver. Based on communications with commercial diving companies in the Portland area (Hutton 2008, Johns 2008, and Burch 2008), the standard of practice for commercial divers is the use of dry suits and helmets when diving in the LWR. However, based on the directive of the EPA, the wet suit diver scenario is also included in this BHHRA~~

3.2.1.4 Transients

~~During past site tours, tents and makeshift dwellings were observed as evidence that individuals were occupying some riverbank areas.~~Transient encampments are known to exist within the Study Area along the Lower Willamette River.~~, though individuals are anticipated to move within or outside the Study Area. While the tents and makeshift dwellings were typically observed above the actual beach areas, transients may contact beach sediment within transient use areas, which are beach areas that are not active industrial sites and are not otherwise restricted from access. Although transients are anticipated to move throughout the Study Area, some may spend a majority of their time at relatively few of the possible areas.~~ While ~~the~~ tents and

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makeshift dwellings are typically observed above actual beach areas, transients ~~may be expected~~ are likely to have direct contact with beach sediment and~~Exposure for a given transient was evaluated in this BHHRA on the basis of a single transient use area, although it is possible that transients move from one transient use area to others within or outside the Study Area. This BHHRA presented an evaluation of individual use areas not only because transients may inhabit single beach areas, but also because such an evaluation provides a range of possible risks for individuals that either move frequently or remain at a single location. Transients may have dermal contact with~~ surface water (including groundwater seeps) during swimming, bathing or other activities, such as washing of clothing or equipment~~. In theory, transientsThey~~, and may also use ~~river~~surface water as a drinking water source~~.~~. Although individuals are anticipated to move within or outside the Study Area~~.~~, ~~S~~some individuals may spend a majority of their time at relatively few areas~~,~~. Thus, ~~and~~ exposure was evaluated as occurring at individual beaches rather than averaged over a larger area~~.~~. ~~River water was assumed to be the sole source of drinking water for transients.~~ Specific locations where exposure by transients was evaluated in the risk assessment are shown on Map 2-1~~.~~. ~~It is not known how long individuals may remain at specific locations or within the Study Area. However, for the purpose of the risk assessment assumed exposure durations of 2 years for the RME and 1 year for CT evaluations. RUse of river water as a source of drinking water by transients was assumed to be their sole source of drinking water for transients.Exposure to surface water by transients would likely occur within transient use areas. Transients may have direct contact with groundwater seeps, within riverfront beach areas that have been identified as transient use areas. While contact with seep water would be unintentional, dermal contact with or incidental ingestion of seep water may occur.~~

3.2.1.5 Recreational Beach Users

A~~Both a~~dults and children participate in recreational activities ~~in beach areas~~at beaches within the Study Area, and the LWR is also used for boating, water skiing, swimming, and other activities~~.~~. ~~ABeach~~The ~~a~~areas currently used for recreational ~~beach~~ activities~~,~~ as well as other areas in the Study Area where sporadic beach use may occur were identified as recreational use areas~~.~~. ~~The LWR is used by both adults and children for boating, water skiing, swimming, and other water activities.~~ While certain individuals may frequent a specific area almost exclusively, others users may regularly use various areas throughout the Study Area~~.~~. Recreational ~~beach users may~~activities are likely to result in ~~contact with~~exposure to beach sediment and ~~within recreational use areas at the Study Area. Some recreational beach users may primarily use a specific recreational use area while other recreational beach users may use various recreational use areas throughout and outside the Study Area. The LWR is used by both adults and children for boating, water skiing, swimming, and other water activities that result in exposure to surface water. Of these activities, exposure to~~ surface water~~.~~. ~~Because specific information regarding the frequency of recreational activities in Portland Harbor is not available, professional judgment was used to assess exposure. An exposure frequency of 94~~

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~~days/year (5 days/week during summer, 1 day/week during spring/fall, and 1 day/month during winter) was used for the RME estimate and 38 days/year (2 days/week during summer, 2 days/month during spring/fall) was used for the CT estimate. would occur to the greatest extent while swimming in the river. Swimming would most likely occur primarily within recreational beach areas.~~

3.2.1.6 Recreational/Subsistence Fishers

A year-round recreational fishery exists within the Study Area~~.~~. Current information ~~suggests~~indicates that spring Chinook salmon, steelhead, Coho salmon, shad, crappie, bass, and white sturgeon are the fish species preferred by local recreational fishers (DEQ 2000b, Hartman 2002, and Steele 2002)~~.~~. In addition to recreational fishing, ~~the~~an investigation by the Oregonian newspaper and ~~the~~ limited surveys conducted on other portions of the Willamette River indicate that immigrants from Eastern Europe and Asia, African-Americans, and Hispanics are most likely to ~~be catching and eating~~use fish from the lower Willamette either as a supplemental or primary dietary source (ATSDR 2002)~~.~~. These ~~preliminary~~ surveys also indicate that the most commonly consumed species are carp, bullhead catfish, and smallmouth bass, ~~(ATSDR 2002). However,~~ although other species may also be consumed~~.~~. ~~C~~In conversations that were conducted as part of a project by the Linnton Community Center (Wagner 2004) ~~with transients~~ about ~~their~~ consumption of fish or shellfish from the Willamette River ~~as part of a project by the Linnton Community Center (Wagner 2004), t.~~ Transients reported consuming a large variety of fish, and several ~~transients~~ said they ate whatever they could catch themselves or ~~get~~obtain from other fishers~~.~~. ~~However, the frequency and amount of consumption was not reported, and many of the transients indicated they were in the area temporarily. Site-specific information is not available for fish consumption rates for specific species, so a range of ingestion rates and various diets were evaluated in this BHHRA for both adult and child consumers~~

~~FishersIndividuals who fish from the water's edge within natural river beach areas couldmay have direct exposurebe exposed to beach sediment. In theory,, and fishing could occur atfrom any beach area withoutwhere restricted access is not restricted. Fishing. from boats or piers couldmay result in exposure to in-water sediment ondue to handling anchors, hooks, or crayfish pots. Exposure to in-water sediments was evaluated for both high- and a low-frequency of fishing in order to assess For in-water sediment exposure, both a high- and a low-frequency fishing scenario were included to evaluate thea range in frequency of fishing activitiesof potential activity patterns.~~

Direct exposures to beach sediments by individuals engaged in recreational or subsistence fishing ~~SThe specific areas evaluated for potential exposure to sediments as areas frequentedfor individuals engaged in by recreationalrecreational or subsistence fishersing and evaluated for potential exposure to sediments include aTherefore, all non-dockside worker use areas (i.e., allareas designated as transient~~

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~~and recreational use areas) were considered potential human use areas where fishers could be exposed to beach sediment. .~~

was evaluated at specific areas designated as transient and recreational use areas, exposures to in-water sediments were evaluated per half mile along each side of the river as well as on a Study Area-wide basis. Fish consumption was evaluated assuming a single-species diet comprised of each individual target resident fish species (smallmouth bass, black crappie, brown bullhead, and common carp), and based on whether only fillets or the whole fish is consumed~~.~~. Exposure was evaluated over fishing zones, based on the relative size of the home range~~s of~~ for each species, as well as averaged over the entire Study Area~~.~~. In addition to the individual species diet, a multiple species diet was also evaluated on a harbor-wide basis, assuming each of the four target species comprised equal portions of the total fish consumption. In order to account for a range of cultural consumption practices, both fillet-only and whole body fish consumption were evaluated.~~Some fishers may primarily use a specific beach area for fishing activities while other fishers may use beach areas throughout and outside the Study Area.~~

~~The extent to which individuals may primarily use a specific beach area for fishing move about throughout and outside the Study Area is unknown. For beach sediment exposure, two different fisher scenarios were included in this BHHRA to evaluate differences in the frequency of fishing activities. High-frequency fishers were assumed to fish recreationally, and at more frequent intervals than the low-frequency fisher (exposure frequency of 156 days per year for high frequency fishers compared to 104 days per year for low-frequency fishers). The extent to which fishing from beach areas actually occurs is unknown, as is the degree of sediment exposure that might occur while fishing. Fishers who fish from boats or piers could be theoretically exposed to in-water sediment on anchors, hooks, or crayfish pots. For in-water sediment exposure, two different fisher scenarios were included in this BHHRA to evaluate differences in the frequency of fishing activities: high-frequency fishers and low-frequency fishers. The extent to which fishing actually occurs under these two scenarios is unknown, as is the degree of sediment exposure that might occur while fishing. However, exposure assumptions provided by EPA were used to evaluate in-water sediment exposure by fishers~~

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3.2.1.7 Tribal Fishers

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The LWR provides a ceremonial and subsistence fishery for Native American tribes~~.~~ ~~. The extent to which tribal members fish within the Study Area, as well as the extent to which that fishing occurs from beach areas and the degree of sediment exposure that might occur while fishing are unknown. However, exposure assumptions provided by EPA were used to evaluate beach sediment exposure by tribal fishers.~~ Four ~~(Yakama, Umatilla, Nez Perce, and Warm Springs) of the six~~ Native American tribes (Yakama, Umatilla, Nez Perce, and Wa~~rm RM~~rm- Springs) ~~involved in the~~

~~Portland Harbor RI/FS~~ participated in a fish consumption survey that was conducted on the reservations of the participating tribes and completed in 1994 ~~(~~[Columbia River Inter-tribal Fish Commission (CRITFC) 1994]~~).~~ . The results of the survey show that tribal members surveyed generally consume more fish than the general public~~.~~ . Certain species, especially salmon and Pacific lamprey, are an important food source as well as an integral part of the tribes' cultural, economic, and spiritual heritage~~.~~ . ~~Consumption of fish by both adult and child tribal members was evaluated in this BHHRA.~~

3.2.1.8 Domestic Water User

Both public and private ~~U~~use ~~As mentioned in Section 2.4.5, lthough there is no known current use of surface water within the Study Area foras a domestic water supply. However, because domestic water use. Because it is a designated beneficial use of the~~of the Willamette River ~~following adequate pretreatment,, the use of untreated river water~~ as a domestic water source is a designated beneficial use of the LWR by the State of Oregon~~.~~ . Hence, use of surface water as a source of household water was assessed as a ~~hypothetical~~potentiall-y complete ~~future~~ pathway ~~for both adult and child residents, at the direction of EPA.~~ . E~~In this scenario, e~~xposure to ~~untreated~~ surface water could ~~hypothetically~~ occur ~~from~~via ingestion and dermal contact throughout the Study Area~~. At the direction of the EPA,~~ , as well as volatilization of chemicals ~~from untreated surface water~~ to indoor air through household ~~uses was identified as a potentially complete exposure pathway for hypothetical future domestic water~~ use~~.~~ .

~~Non-tribal Fishers~~

~~Fishers who fish from the water's edge within natural river beach areas could have direct exposure to beach sediment. In theory, fishing could occur at any beach area without restricted access. Therefore, all non-dockside worker use areas (i.e., all transient and recreational use areas) were considered potential human use areas where fishers could be exposed to beach sediment. Some fishers may primarily use a specific beach area for fishing activities while other fishers may use beach areas throughout and outside the Study Area.~~

~~For beach sediment exposure, two different fisher scenarios were included in this BHHRA to evaluate differences in the frequency of fishing activities. High-frequency fishers were assumed to fish recreationally, and at more frequent intervals than the low-frequency fisher (exposure frequency of 156 days per year for high frequency fishers compared to 104 days per year for low-frequency fishers). The extent to which fishing from beach areas actually occurs is unknown, as is the degree of sediment exposure that might occur while fishing.~~

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~~1.1~~3.3 IDENTIFICATION OF EXPOSURE PATHWAYS

Exposure pathways are defined as the physical ways in which chemicals may enter the human body ~~(e.g., ingestion, inhalation, dermal absorption).~~ . A complete exposure pathway consists of the following four elements:

- A source of chemical release
- A release or transport mechanism (or media in cases involving media transfer)
- An exposure point (a point of potential human contact with the contaminated exposure medium)
- An exposure route (e.g., ingestion, dermal contact) at the exposure point.

If any of the above elements is missing, the pathway is considered incomplete and exposure does not occur.

~~As discussed in Sections 4, 5, and 6 of the RI Report, the affected media within the Study Area are sediment, water, and biota. Current and historical industrial activities and processes within, upstream and downstream of the Study Area may have led to chemical releases from either point or nonpoint sources to the Study Area. In addition to these releases, discharges to the river from outfalls and groundwater within the Study Area may be potentialhave also contributed to contamination contaminant sources to the Study Area. Finally, releases that occur upstream and downstream of the Study Area and global, regional, and local emissions resulting in atmospheric deposition may be potential sources to the Study Area. These potential sources and release mechanisms are discussed in greater detail in Section 4 of the RI Report.~~

~~Chemicals in sediment and water may be accumulated by organisms in the water column or associated with the sediments. Edible fish and shellfish species feeding on these organisms and living within the Study Area may accumulate chemicals in their tissues through dietary exposures and direct exposure to sediment and water.~~ The potential exposure pathways to human populations at the Study Area include:

- Incidental ~~Ingestion~~ ingestion of and dermal contact with beach sediment
- Incidental ingestion ~~of~~ and dermal contact with in-water sediment
- Incidental ingestion ~~of~~ and dermal contact with surface water
- Incidental ingestion ~~of~~ and dermal contact with surface water from ~~groundwater~~ seeps
- ~~Ingestion~~ Consumption of fish and shellfish
- Infant consumption of human milk.

~~Dockside Workers~~

~~Dockside workers include industrial and commercial workers at facilities adjacent to the river who conduct specific activities within natural river beach areas, such as unloading ships or barges from the beach itself or conducting occasional maintenance activities from the water's edge. The actual activities that occur within natural river beach areas are site-specific and generally occur only very infrequently. Although exposure is anticipated to be infrequent, workers conducting activities within natural river beach areas may contact beach sediment within riverfront industrial and commercial sites at the Study Area. Exposure for a given worker would occur only within the defined dockside worker use area adjacent to the facility of that worker.~~

~~Transients~~

~~During past site tours, tents and makeshift dwellings were observed as evidence that individuals were occupying some riverbank areas. While the tents and makeshift dwellings were typically observed above the actual beach areas, transients may contact beach sediment within transient use areas, which are beach areas that are not active industrial sites and are not otherwise restricted from access. Although transients are anticipated to move throughout the Study Area, some may spend a majority of their time at relatively few of the possible areas. Exposure for a given transient was evaluated in this BHHRA on the basis of a single transient use area, although it is possible that transients move from one transient use area to others within or outside the Study Area. This BHHRA presented an evaluation of individual use areas not only because transients may inhabit single beach areas, but also because such an evaluation provides a range of possible risks for individuals that either move frequently or remain at a single location.~~

~~Recreational Beach Users~~

~~Both adults and children participate in recreational activities in beach areas within the Study Area. Areas currently used for recreational beach activities, as well as other areas in the Study Area where sporadic beach use may occur were identified as recreational use areas. Recreational beach users may contact beach sediment within recreational use areas at the Study Area. Some recreational beach users may primarily use a specific recreational use area while other recreational beach users may use various recreational use areas throughout and outside the Study Area.~~

~~Tribal Fishers~~

~~The LWR provides a ceremonial and subsistence fishery for Native American tribes. The extent to which tribal members fish within the Study Area, as well as the extent to which that fishing occurs from beach areas and the degree of sediment exposure that might occur while fishing are unknown. However, exposure assumptions provided by EPA were used to evaluate beach sediment exposure by tribal fishers.~~

~~**Non-tribal Fishers**~~

~~Fishers who fish from the water's edge within natural river beach areas could have direct exposure to beach sediment. In theory, fishing could occur at any beach area without restricted access. Therefore, all non-dockside worker use areas (i.e., all transient and recreational use areas) were considered potential human use areas where fishers could be exposed to beach sediment. Some fishers may primarily use a specific beach area for fishing activities while other fishers may use beach areas throughout and outside the Study Area.~~

~~For beach sediment exposure, two different fisher scenarios were included in this BHHRA to evaluate differences in the frequency of fishing activities. High-frequency fishers were assumed to fish recreationally, and at more frequent intervals than the low-frequency fisher (exposure frequency of 156 days per year for high frequency fishers compared to 104 days per year for low-frequency fishers). The extent to which fishing from beach areas actually occurs is unknown, as is the degree of sediment exposure that might occur while fishing.~~

~~Section 3.3 provides a~~A more detailed discussion of potential exposures for the Study Area under current~~, reasonably foreseeable~~ and ~~hypothetical~~ future conditions, and presents the rationale for including or eliminating pathways from quantitative evaluation~~.~~. The identified receptors, exposure routes, and exposure pathways, and the rationale for selection are also summarized in Table 3-1.

~~1.1.1 Definition and Significance of Exposure Pathways~~

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Exposure pathways are designated in one of the following four ways:

Potentially Complete: There is a source or release from a source, an exposure point where contact can occur, and an exposure route by which contact can occur~~.~~. Pathways considered potentially complete are quantitatively evaluated in this BHHRA.

Potentially Complete ~~and~~ but Insignificant: There is a source or release from a source, an exposure point where contact can occur, and an exposure route by which contact can occur~~;~~ . ~~however~~However, ~~the~~ exposure via the pathway is ~~considered a~~ likely to be negligible relative ~~contributor~~ to the overall risk~~.~~. Pathways considered potentially complete ~~and~~ but insignificant were not evaluated further in this BHHRA.

Incomplete: There is no source or release from a source, no exposure point where contact can occur, or no exposure route by which contact can occur for the given receptor~~.~~. Pathways considered potentially incomplete were not evaluated further in this BHHRA.

Potentially complete pathway, but evaluated ~~under~~ for a different receptor ~~category~~: These pathways may be complete for some individuals~~ in this receptor category due to overlapping exposure scenarios (e.g., some in-water workers may~~

~~also be fishers)~~, but are not evaluated for the identified receptor ~~category~~ because the pathways are not considered ~~relevant~~ typical for that receptor~~.~~. These pathways are evaluated ~~under~~ for different receptors ~~categories~~ where the pathways are considered potentially complete and significant~~.~~. Overlapping exposures that may occur for the different receptors ~~categories~~ are discussed further in Section 3.3.~~7 of this BHHRA.~~

~~1.1.2 Conceptual Site Model~~

~~2.0 The conceptual site model (CSM) for human exposures based on the current understanding of the Study Area and requirements from EPA is presented in Figure Figure 3-1. The CSM graphically depicts possible sources of COPCs based on current information, possible COPC-affected media, mechanisms of COPC transfer between media, and the processes through which human receptors may be exposed to chemicals. Additional information on potential sources of COPCs is provided in Section 5 of the RI Report. Potentially complete exposure pathways were identified in the Programmatic Work Plan or based on subsequent requirements from EPA. In-water workers exposure to river sediment, transients exposure to shoreline seeps, divers exposure to surface water and in-water sediment, infant exposure via consumption of human milk for all receptors with bioaccumulative COPCs, and hypothetical future exposures of domestic water users to surface water were included as potentially complete pathways per requirements from EPA. Pathways that are potentially or hypothetically complete and may result in significant exposure, or for which significance is unknown, were evaluated quantitatively in this BHHRA, per direction from EPA. Pathways included at the direction of EPA include clam consumption, exposure to surface water and in-water sediment by a commercial diver, and hypothetical exposure to untreated surface water by a domestic water user.~~

~~2.1 EXPOSURE SCENARIOS~~

The following sections provide a more detailed discussion of the exposure ~~scenarios~~ pathways that are quantitatively evaluated in this BHHRA~~.~~. ~~The following exposure scenarios were identified based on exposures that may generically occur throughout the Study Area and do not consider site-specific conditions that may limit exposure at a given location.~~

~~2.1.1~~3.3.1 Direct Exposure to Beach Sediment

Based on current and future uses within the Study Area, ~~Incidental~~ incidental ingestion ~~of~~ and dermal contact with beach sediment could occur within natural river beach areas ~~used by human populations within the Study Area. These areas were~~ identified as human use areas in the Programmatic Work Plan~~, based on current and future uses within the Study Area.~~. ~~Human use~~These areas were further classified ~~based~~ with respect to ~~on~~ the type of exposures that could occur, ~~at these beaches~~ including recreational, recreational/subsistence and tribal ~~fishers~~fishing~~, tribal fishers~~, transient, or dockside worker use areas~~.~~. ~~These classifications are described in~~

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~~greater detail below. The~~ H~~h~~uman use areas in the Study Area and their associated classifications are shown in Map 2-1~~.~~.

Direct exposure to beach sediments is considered to be a complete pathway for dockside workers, transients, recreational beach users, and both recreational/subsistence and tribal fishers~~.~~.

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~~**2.1.1.1** Exposure frequency for dockside workers was assumed to be 200 days/year for the RME evaluation, and 50 days/year the CT evaluationDockside Workers~~

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~~2.0 Dockside workers include industrial and commercial workers at facilities adjacent to the river who conduct specific activities within natural river beach areas, such as unloading ships or barges from the beach itself or conducting occasional maintenance activities from the water's edge. The actual activities that occur within natural river beach areas are site-specific and generally occur only very infrequently. Although exposure is anticipated to be infrequent, workers conducting activities within natural river beach areas may contact beach sediment within riverfront industrial and commercial sites at the Study Area. Exposure for a given worker would occur only within the defined dockside worker use area adjacent to the facility of that worker.~~

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~~**2.1.1.2** Transients~~

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~~3.0 During past site tours, tents and makeshift dwellings were observed as evidence that individuals were occupying some riverbank areas. While the tents and makeshift dwellings were typically observed above the actual beach areas, transients may contact beach sediment within transient use areas, which are beach areas that are not active industrial sites and are not otherwise restricted from access. Although transients are anticipated to move throughout the Study Area, some may spend a majority of their time at relatively few of the possible areas. Exposure for a given transient was evaluated in this BHHRA on the basis of a single transient use area, although it is possible that transients move from one transient use area to others within or outside the Study Area. This BHHRA presented an evaluation of individual use areas not only because transients may inhabit single beach areas, but also because such an evaluation provides a range of possible risks for individuals that either move frequently or remain at a single location.~~

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~~**2.1.1.3** Recreational Beach Users~~

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~~4.0 Both adults and children participate in recreational activities in beach areas within the Study Area. Areas currently used for recreational beach activities, as well as other areas in the Study Area where sporadic beach use may occur were identified as recreational use areas. Recreational beach users may contact beach sediment within recreational use areas at the Study Area. Some recreational beach users may primarily use a specific recreational use area while other recreational beach users may use various recreational use areas throughout and outside the Study Area.~~

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~~**2.1.1.4** Tribal Fishers~~

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~~5.0 The LWR provides a ceremonial and subsistence fishery for Native American tribes. The extent to which tribal members fish within the Study Area, as well as the extent to which that fishing occurs from beach areas and the degree of sediment exposure that might occur while fishing are unknown. However, exposure assumptions provided by EPA were used to evaluate beach sediment exposure by tribal fishers.~~

~~**2.1.1.5** Non-tribal Fishers~~

~~6.0 Fishers who fish from the water's edge within natural river beach areas could have direct exposure to beach sediment. In theory, fishing could occur at any beach area without restricted access. Therefore, all non-dockside worker use areas (i.e., all transient and recreational use areas) were considered potential human use areas where fishers could be exposed to beach sediment. Some fishers may primarily use a specific beach area for fishing activities while other fishers may use beach areas throughout and outside the Study Area.~~

~~7.0 For beach sediment exposure, two different fisher scenarios were included in this BHHRA to evaluate differences in the frequency of fishing activities. High-frequency fishers were assumed to fish recreationally, and at more frequent intervals than the low-frequency fisher (exposure frequency of 156 days per year for high frequency fishers compared to 104 days per year for low-frequency fishers). The extent to which fishing from beach areas actually occurs is unknown, as is the degree of sediment exposure that might occur while fishing.~~

~~**2.1.1.6** Potentially Complete and Insignificant Exposure Pathways~~

~~8.0 This BHHRA did not identify any potentially complete and insignificant exposure pathways for beach sediment exposure.~~

~~**2.1.1.7** Incomplete Exposure Pathways~~

~~Beach sediment exposures are considered incomplete exposure pathways for both in-water workers and divers based on the defined activities of these receptor populations in this BHHRA. In-water workers are those workers who conduct over water activities and thus are not directly exposed to beach sediments. Dockside workers are the worker population for which beach sediments exposures are considered potentially complete and were evaluated in this BHHRA. Divers conduct activities in the river that do not result in beach sediment exposures. The hypothetical future domestic water use scenario evaluates use of surface water for domestic water supply and thus beach sediment exposures were considered incomplete exposure pathways for this receptor population. . The value of 200 days/year is slightly less than the EPA default exposure frequency of 225 days/year for outdoor workers, which , and . This value represents the average number of days worked forper year by male and female workers from according to the U.S. Census Bureau's *1990 Earnings by Occupation and Education Survey*. An exposure duration of 25 years was used, representing an EPA default value for the RME estimate of job tenure. This value is consistent with data from the U.S. Bureau of Labor Statistics showing that the 95th percentile job tenure offor men in the manufacturing sector is 25 years. The CT estimate assumed duration of 9 years.~~

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~~representing approximately the 50th percentile of residence time estimates from the U.S. Census Bureau data (EPA, 1997). A soilsediment ingestion rate of 200 mg/day was used for the RME evaluation, based on EPA Region 10 supplemental guidance on soil ingestion rates (EPA, 2000a), and is representative of approximately the midpoint between the recommended value of 100 mg/day for outdoor workers and 330 mg/day for construction workers. An ingestion rate of 50 mg/day was used to estimate CT exposure. Dermal exposure was assessed assuming that the face, forearms and hands are exposed, representing an exposed skin surface area of 3,300 cm^2, which is representative of the median value (50th percentile) for adults.~~

~~Exposure frequency for transients was assumed to be daily (365 days/year). It is not known how long individuals may remain at specific locations or within the Study Area. Based on professional judgment, an exposure durations of 2 years was assumed for the RME and 1 year for CT evaluations. SoilIncidental ingestion of sediment was evaluated at the same rates used for the dockside workers. Dermal exposure was assessed assuming that the face, forearms and hands, and lower legs are exposed, representing an exposed skin surface area of 5,700 cm^2, representing the median value for adults.~~

~~Specific information regarding the frequency of recreational activities in Portland Harbor is not available. Hence, professional judgment was used to assess exposure. An exposure frequency of 94 days/year (5 days/week during summer, 1 day/week during spring/fall, and 1 day/month during winter) was used for the RME estimate and 38 days/year (2 days/week during summer, 2 days/month during spring/fall) was used for the CT estimate. Exposure duration for recreational activities is based on the assumption that individuals are largely permanent residents of the Portland area. An exposure duration of 30 years, which represents approximately the 95th percentile of the length of continuous residence in a single location in the U.S. population (EPA, 1997) was used for the RME estimate. More recent studies described in 2011 edition of EPA's Exposure Factors Handbook show the 95th percentile value is closer to 33 years, data from the U.S. Census Bureau indicate that 32 years represents the best estimate of residence time at the 90th percentile. However, the value of 30 years is consistent with other Superfund risk assessments nationwide, and represents a reasonably conservative estimate of total residence time in the area. An exposure duration of 9 years was used for the CT estimate. ISoil ingestion rates of 100 mg/day for adults and 200 mg/day for children were used, approximating the 95th percentile soil ingestion rates. Central tendencyCT estimates assumed sediment ingestion rates of 100 mg/day for children and 50 mg/day for adults. Dermal exposures were evaluated assuming that the face, forearms and hands, and lower legs are exposed. Median values of 5,700 cm^2 and 2,800 cm^2 were used for adults and children, respectively.~~

~~As discussed in Section 3.2.1.6, a range of possible exposures was evaluated for people who engage in recreational or subsistence fishing activities by considering both a high-frequency and a low-frequency rate of fishing. RME estimates for hHigh-frequency fishers were assumed to fishfishing at more frequent intervals than the low-frequency fisher (exposure frequency of 156 days/ per year , approximating a rate of 3 days/week. Low-frequency fishers were assumed to fishfor high frequency fishers compared to 104 days/ per year,~~

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~~approximating a rate of 2 days/week. CT estimates assumed a frequency 52 days/year and 26 days/year for high- and low-frequency fishers, respectively, and are representative of assumed fishing frequencies of 1 day/week and 2 days/month. The exposure duration for recreational and subsistence fishers is based on the assumption that they are largely permanent residents of the Portland area. An exposure duration of 30 years, which represents approximately the 95th percentile of the length of continuous residence in a single location in the U.S. population (EPA, 1997) was used for the RME estimate. More recent studies described in 2011 edition of EPA's Exposure Factors Handbook show the 95th percentile value is closer to 33 years, data from the U.S. Census Bureau indicate that 32 years represents the best estimate of residence time at the 90th percentile. However, the value of 30 years is consistent with other Superfund risk assessments nationwide, and represents a reasonably conservative estimate of total residence time in the area. An exposure duration of 9 years was used for the CT estimate, representing approximately the 50th percentile of residence time estimates from the U.S. Census Bureau data (EPA, 1997).Dermal exposure was evaluated assuming the same exposed skin surface area for adults of 5,700 cm² used for recreational exposure. People engaged in recreational or subsistence fishing were also assumed to be residents of the Portland area, therefore exposure durations of 30 years and 9 years were used for the RME and CT evaluation, respectively.~~

~~Sediment ingestion rates for tribal fishers were evaluated at the same rate as for recreational/subsistence fishers. Fishing frequency was assumed to be 260 days/yr (5 days/week) for the RME estimate and 104 days/year (2 days/week) for the CT estimate. Specific information regarding population mobility on native American populations is less readily available than for the general U.S. population. However, input during the scoping of the Portland Harbor risk assessment indicated that this population should be considered less mobile for a variety of reasons. Hence, the evaluation of exposures to native Americans was based on the premise that they spend their entire lives in the area, and a typical lifetime was evaluated as being 70 years. for low-frequency fishers).~~

~~2.1.2~~3.3.2 Direct Exposure to In-Water Sediment

~~Ingestion of and dermal~~Direct contact with in-water sediment could occur ~~through over-water~~during activities ~~(i.e., activities~~ conducted from a boat or other vessel~~)~~ that result in bringing sediment to the ~~river's~~ surface, during diving, or when fishing as a result of handling anchors, hooks, or crayfish pots~~.~~. Hence, direct exposure to in-water sediment is considered to be a complete pathway for in-water workers, divers, ~~and~~ recreational/subsistence and tribal fishers~~.~~. Although recreational beach users may contact in-water sediment while swimming, such exposures are not expected to be significant and were not quantitatively evaluated in the risk assessment~~.~~. ~~In-water sediment exposures were considered potentially complete and insignificant exposure pathways for recreational beach users and were not quantitatively evaluated.~~ Exposure to in-water sediment was evaluated throughout the Study Area by river mile rather than ~~as having the potential to occur only in~~ at specific areas~~,~~ as was done ~~for~~with exposure to beach sediments~~.~~.

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~~Exposure factors used for in-water workers were developed based on in-depth interviews with several workers at Terminal 4 who conduct or oversee activities that could result in direct contact with in-water sediment. RME exposures were assessed assuming an exposure frequency of 10 days/year for a total exposure duration of 10 years, CT exposures are assumed at 4 days/year for 4 years. Incidental ingestion of sediment was evaluated assuming the same ingestion rates used for beach sediment, 200 mg/day for the RME evaluation and 50 mg/day for the CT evaluation. An exposed skin surface area of 3,300 cm² for adults was used to assess dermal exposure.~~

~~Two different scenarios were evaluated for direct exposure to in-water sediments by divers, based on whether the divers wear wet or dry suits. Divers wearing wet suits are assumed to be commercial divers without a full face mask, and wearing either wet gloves or no gloves. An exposure frequency of 5 days/year for the RME evaluation and 2 days/year for the CT evaluation are based on best professional judgment and discussions between EPA, LWG, and commercial divers, as well as the experience of EPA divers who work at the Portland Harbor Superfund site. EThe exposure durations of 25 years and 9 years arewere used for the RME and CT estimates, respectively. Sediment ingestion rates were assumed to be 50 percent of dockside workers, corresponding to values of 50 mg/day and 25 mg/day, respectively for the RME and CT evaluations. Dermal exposure to sediment was evaluated assuming the entire skin surface area was exposed. A value of 18,150 cm², representing the median for men and women was used for both the RME and CT evaluations. Divers wearing a dry suit (with a neck dam) would likely have only their head, neck, and hands exposure, and a RME value of 2,510 cm² was used. A CT evaluation was not done for divers wearing dry suits.~~

~~Exposure to in-water sediment for people engaged in recreational/subsistence fishing are generally the same as those used to assess exposure to beach sediments. Incidental ingestion of sediment The exposure assumptions were developed by EPA Region 10~~

~~where exposure would be possible. Unlike the beach sediment exposure scenarios that are restricted to specific beach areas, potential exposure to in-water sediment could occur anywhere that over-water activities occur. As a result, direct exposure to in-water sediment was evaluated throughout the Study Area. At the direction of the EPA, exposure to in-water sediment by divers is also evaluated in this BHHRA.~~

~~2.1.2.1 In-Water Workers~~

~~3.0 While this population is referred to as "in-water" workers, these workers are not actually in the water. Rather, in-water workers are those workers who conduct over-water activities such as maintenance dredging and repair of in-water structures. Exposure to in-water sediment could occur while performing these specific activities, although most maintenance dredging activities are mechanical and are unlikely to result in significant sediment contact. Although likely occurring less frequently than~~

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~~mechanical dredging activities, other activities such as maintenance and cleaning of equipment or in off-loading sediments to disposal sites may result in a greater exposure potential.~~

~~3.1.1.1 Divers~~

~~4.0 In the Study Area, the majority of divers are expected to be commercial divers. To evaluate diver exposures, two different exposure scenarios are included in this BHHRA, one assuming that a wet suit is worn during diving and one assuming that a dry suit is worn during diving. The diver exposure scenarios were directed by EPA in a memorandum regarding the *Proposed Commercial Diver Exposure Scenario for the Portland Harbor Risk Assessment* (EPA 2008c). Both the wet suit and dry suit diver exposure scenarios assume that the diver is exposed to sediment through inadvertent ingestion of sediment and dermal exposure to sediment. As EPA stated in its approach, the use of a dry suit is expected to limit diver exposure, so it is assumed that the wet suit diver has more dermal exposure to sediment than the dry suit diver. Based on communications with commercial diving companies in the Portland area (Hutton 2008, Johns 2008, and Burch 2008), the standard of practice for commercial divers is the use of dry suits and helmets when diving in the LWR. However, based on the directive of the EPA, the wet suit diver scenario is also included in this BHHRA.~~

~~5.0~~

~~5.1.1.1 Tribal Fishers~~

~~9.0 The LWR provides a ceremonial and subsistence fishery for Native American tribes. The extent to which tribal members fish within the Study Area, as well as the extent to which that fishing occurs from boats or piers and the degree of sediment exposure that might occur while fishing are unknown. However, exposure assumptions provided by EPA were used to evaluate in-water sediment exposure by tribal fishers.~~

~~10.0~~

~~5.1.1.2 Non-tribal Fishers~~

~~11.0 Fishers who fish from boats or piers could be theoretically exposed to in-water sediment on anchors, hooks, or crayfish pots. For in-water sediment exposure, two different fisher scenarios were included in this BHHRA to evaluate differences in the frequency of fishing activities: high-frequency fishers and low-frequency fishers. The extent to which fishing actually occurs under these two scenarios is unknown, as is the degree of sediment exposure that might occur while fishing. However, exposure assumptions provided by EPA were used to evaluate in-water sediment exposure by fishers.~~

~~5.1.1.3 Potentially Complete and Insignificant Exposure Pathways~~

~~Recreational beach users could contact in-water sediment while swimming. However, any exposure to in-water sediment is expected to be minimal and the exposure would occur under water, so it cannot be quantitatively evaluated using EPA exposure models. In-water sediment exposures were considered potentially~~

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~~complete and insignificant exposure pathways for recreational beach users and were not quantitatively evaluated in this BHHRA.~~

~~5.1.1.4 Incomplete Exposure Pathways~~

~~In-water sediment exposures were considered incomplete exposure pathways for dockside workers and transients based on the defined activities of these receptor populations in this BHHRA. Dockside workers are those workers who conduct specific activities within natural river beach areas and thus are not directly exposed to in-water sediments. In-water workers are the worker population for which in-water sediments exposures are considered potentially complete and were evaluated in this BHHRA. Transients who conduct specific activities while occupying natural river beach areas are unlikely to contact in-water sediment. The hypothetical future domestic water use scenario evaluates use of surface water for domestic water supply and thus in-water sediment exposures are considered incomplete exposure pathways for this receptor population.~~

~~5.1.2~~3.3.3 Direct Exposure to Surface Water

Direct exposure to contaminants in surface water could ~~potentially~~ occur during recreational~~al~~ or occupational activities that occur near ~~o~~for in the water~~.~~. Transients may also use surface water ~~, either from groundwater seeps or the lower Willamette,~~ as a source of drinking water or for bathing~~.~~. Accordingly, direct exposure via ingestion and dermal contact with surface water is considered to be a complete pathway for transients, recreational beach users, and divers.~~occur for many of the populations evaluated in this BHHRA. Two populations expected to potentially have the most frequent contact with surface water are transients and recreational beach users. At the direction of the EPA, exposure to surface water by divers and the hypothetical future use of untreated surface water as a domestic water source are also evaluated in this BHHRA.~~

~~5.1.2.1 Transients~~

~~12.0 Transients may have dermal contact with surface water during swimming, bathing or other activities, such as washing of clothing or equipment. In theory, transients may also use river water as a drinking water source. Exposure to surface water by transients would likely occur within transient use areas.~~

~~5.1.2.2 Divers~~

~~13.0 As described in Section 3.3.2.2, two different diver exposure scenarios are included in this BHHRA. The two exposure scenarios for divers differentiate between the use of either a wet suit or dry suit, as directed by the EPA (2008c). Both the wet suit and dry suit diver exposure scenarios assume that the diver is exposed to surface water through inadvertent ingestion of surface water and dermal exposure to surface water. TAs EPA stated in its approach, the use of a dry suit is expected to limit diver~~

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~~exposure, so a diver using a wet suit is assumed to have more greater potential for dermal exposure to surface water.~~

~~5.1.2.3 Recreational Beach Users~~

~~14.0 The LWR is used by both adults and children for boating, water skiing, swimming, and other water activities that result in exposure to surface water. Of these activities, exposure to surface water would occur to the greatest extent while swimming in the river. Swimming would likely occur primarily within recreational beach areas.~~

~~5.1.2.4 Domestic Water User~~

~~As mentioned in Section 2.4.5, there is no known current use of surface water within the Study Area for a domestic water supply. However, because domestic water use is a designated beneficial use of the Willamette River following adequate pretreatment, the use of untreated river water as a domestic water source was assessed as a hypothetical future pathway for both adult and child residents, at the direction of EPA. In this scenario, exposure to untreated surface water could hypothetically occur from ingestion and dermal contact throughout the Study Area. At the direction of the EPA, volatilization of chemicals from untreated surface water to indoor air through household uses was identified as a potentially complete exposure pathway for hypothetical future domestic water use.~~

~~5.1.2.5 Potentially Complete and Insignificant Exposure Pathways~~

E~~Surface water e~~xposure to contaminants in surface waters ~~through~~ via dermal absorption and ingestion were considered potentially complete ~~and~~ but insignificant ~~exposure~~ pathways for dockside workers, in-water workers, tribal fishers, and fishers~~.~~. It is unlikely that ~~both~~ dockside and in-water ~~populations~~ workers would have direct contact with surface water ~~through industrial activities~~on a regular basis, and the potential for significant exposure is considered low for ~~. It is also unlikely that~~recreational/subsistence and tribal fishers~~and fishers would have significant direct contact with surface water through fishing activities.~~ . ~~Any exposures to surface water by the dockside workers, in-water workers, tribal fishers, or fishers would be minimal; therefore, surface water exposures were considered potentially complete and insignificant exposure pathways for these receptor populations.~~Additionally,

although contaminants may volatilize~~Volatilization of chemicals~~ from surface water to outdoor air, it is unlikely to result in a significant exposure considering the amount of mixing with ambient air ~~that would occur~~and the relatively low concentrations of VOCs in surface water. ~~Given the low levels of chemicals in outdoor air from volatilization from surface water, surface water exposures through~~Hence, inhalation of volatiles to outdoor air was considered a potentially complete ~~and~~ but insignificant exposure pathway for all receptor~~populations~~s ~~who conduct outdoor activities.~~ .

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~~5.1.2.6 Incomplete Exposure Pathways~~

~~This BHHRA did not identify any incomplete exposure pathways for surface water exposures.~~

~~5.1.3~~3.3.4 Direct Exposure to Groundwater from Seeps

Direct contact with groundwater ~~would~~ is assumed to occur only at seeps ~~only within human use areas~~ where groundwater comes to the surface ~~(i.e., seeps)~~ on ~~the~~ a beach above the water line~~—~~. Direct exposure to groundwater via seeps ~~and~~ is ~~only~~ considered a potentially complete exposure pathway for transients and recreational beach users~~—~~. As described in Section 2.1.4, a seep reconnaissance survey ~~there was~~ identified only ~~one a single groundwater seep,~~ Outfall 22B, which is ~~identified during the seep reconnaissance survey that has not been remediated and is~~ located at approximately ~~RM~~ RM 7W in an area designated ~~for the risk assessment~~ as ~~recreational or~~a potentially used by transients ~~use area.~~. ~~That seep, which is the potential groundwater discharge from Outfall 22B, occurs within a potential transient use area.~~ Therefore, exposure to surface water from the groundwater seeps at Outfall 22B ~~only transients were~~was ~~only~~ evaluated ~~for~~ only for transients~~for exposure to groundwater seeps in theis BHHRA~~.

~~5.1.3.1~~ Consumption of ~~Transients~~

~~Transients may have direct contact with groundwater seeps, within riverfront beach areas that have been identified as transient use areas. While contact with seep water would be unintentional, dermal contact with or incidental ingestion of seep water may occur.~~

~~5.1.3.2 Potentially Complete and Insignificant Exposure Pathways~~

~~This BHHRA did not identify any potentially complete and insignificant exposure pathways for direct exposure to groundwater seeps.~~

~~5.1.3.3 Incomplete Exposure Pathways~~

~~Direct exposure to groundwater seeps were considered incomplete exposure pathways for all receptor populations who do not conduct activities at beaches where groundwater discharges above the water line. As discussed above, only one groundwater seep was identified, which is within a transient use area. Therefore, direct exposure to groundwater seeps is considered an incomplete exposure pathway for dockside and in-water workers, recreational beach users, tribal fishers, fishers, and divers. The hypothetical future domestic water use scenario evaluates use of surface water for domestic water supply and thus groundwater seep exposures were considered incomplete exposure pathways for this receptor population.~~

~~5.1.4~~3.3.5 Fish ~~Consumption~~

~~Certain chemicals may~~Many of the contaminants found in Portland Harbor are persistent in the environment and accumulate ~~through~~in the food-chain ~~bioaccumulate~~

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~~in fish tissue, including fish. .~~ ~~and human populations~~Local populations ~~that~~ who consume fish caught in Portland Harbor may be exposed to COPCs ~~bioaccumulating~~ that ~~have~~ bioaccumulated in ~~the~~ fish ~~tissues. .~~ ~~Fish may be caught throughout the Study Area.~~ While the populations evaluated in this BHHRA are described as "fishers,"~~,~~ the fish consumption evaluation in this BHHRA includes people who consume fish caught within the Study Area, not just those who catch the fish~~. .~~. Consumption of locally-caught fish is evaluated as a complete exposure pathway for

~~5.1.4.1 Non-tribal Fishers~~

~~A year-round recreational fishery exists within the Study Area. Current information suggests that spring Chinook salmon, steelhead, Coho salmon, shad, crappie, bass, and white sturgeon are the fish species preferred by local recreational fishers (DEQ 2000b, Hartman 2002, and Steele 2002). In addition to recreational fishing, the investigation by the Oregonian newspaper and the limited surveys conducted on other portions of the Willamette River indicate that immigrants from Eastern Europe and Asia, African-Americans, and Hispanics are most likely to be catching and eating fish from the lower Willamette (ATSDR 2002). These preliminary surveys also indicate that the most commonly consumed species are carp, bullhead catfish, and smallmouth bass (ATSDR 2002). However, other species may also be consumed. Conversations were conducted with transients about their consumption of fish or shellfish from the Willamette River as part of a project by the Linnton Community Center (Wagner 2004). Transients reported consuming a large variety of fish, and several transients said they ate whatever they could catch themselves or get from other fishers. However, the frequency and amount of consumption was not reported, and many of the transients indicated they were in the area temporarily. Site-specific information is not available for fish consumption rates for specific species, so a range of ingestion rates and various diets were evaluated in this BHHRA for both adult and child consumers.~~

~~5.1.4.2 Tribal Fishers~~

~~Four (Yakama, Umatilla, Nez Perce, and Warm Springs) of the six Native American tribes involved in the Portland Harbor RI/FS participated in a fish consumption survey that was conducted on the reservations of the participating tribes and completed in 1994 (Columbia River Inter-tribal Fish Commission (CRITFC) 1994). The results of the survey show that tribal members surveyed generally have higher fish ingestion rates than~~~~consume more fish than~~ ~~the general public. Fish~~ ~~Certain~~ ~~species, especially salmon and Pacific lamprey, are an important food source as well as an integral part of the tribes' cultural, economic, and spiritual heritage. Ingestion~~ ~~Consumption~~ ~~of fish by both adult and child tribal members was evaluated in this BHHRA.~~

~~3.1.1.1 Potentially Complete but Evaluated Under a Different Receptor Category~~

~~Fish could be consumed by~~ dockside workers, in-water workers, recreational beach users, and divers. ~~; however, fish~~ ~~C~~consumption of fish by these ~~receptor~~ populations is evaluated under the ~~fisher~~ recreational/subsistence receptor ~~category. .~~ ~~. Bty~~ definition, ongoing ~~Long~~long-term~~,~~ ~~ongoing~~ fish consumption by transients would not be expected to occur~~; .~~, -and the evaluation of fish consumption for other

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~~5.1.4.3~~ Consumption of ~~Incomplete Exposure Pathways~~

~~The hypothetical future domestic water use scenario evaluates use of surface water for domestic water supply and thus fish consumption was considered an incomplete exposure pathway for this receptor population.~~

~~5.1.5~~3.3.6 Shellfish ~~Consumption~~

Certain contaminants can bioaccumulate in s~~Like fish, s~~hellfish ~~may bioaccumulate certain chemicals in their tissue~~, and ~~. P~~populations ~~that consume shellfish~~ may be exposed to COPCs through consumption of shellfish that are ~~that accumulate in the shellfish tissue~~collected within the Study Area~~. ~~. ~~In the Programmatic Work Plan, crayfish was identified as the species to use to evaluate shellfish consumption. Additionally, as required by EPA, consumption of clams is also evaluated in this BHHRA. Harvest and possession of Asian clams, which is the clam species that was found in the LWR during sampling events, is illegal in the State of Oregon because Asian clams are on the prohibited species list of the ODFW rules regarding the importation, possession, confinement, transportation and sale of nonnative wildlife (OAR 635-056-0050).~~

~~5.1.5.1 Fishers~~

~~SHowever,In theory, shellfish consumption could may occur throughout the Study Area wherever shellfish are found~~ T~~. However, it is not known to what~~the actual extent shellfish harvesting and consumption is presently ~~occurs~~occurring is not known~~. ~~.

The Linnton Community Center project (Wagner 2004) reported that some transients reported eating clams and crayfish,~~;~~ ~~however~~although~~,~~ many of the individuals indicated that they were in the area temporarily, move from location to location frequently, or have variable diets based on what is easily available~~. ~~. The Superfund Health Investigation and Education (SHINE) program in the Oregon Department of Human Services (DHS) stated that is unknown whether or not crayfish are harvested commercially within Portland Harbor (ATSDR 2006)~~. ~~. ODFW has records for crayfish collection in the Columbia and Willamette Rivers, but these records do not indicate whether the collection actually occurs within the Study Area~~. ~~. Based on ODFW's data for 2005 to 2007, no commercial crayfish landings were reported for the Willamette River in Multnomah County~~. ~~. DHS had previously received information from ODFW indicating that an average of 4,300 pounds of crayfish were harvested commercially from the portion of the Willamette River within Multnomah

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County each of the five years from 1997-2001~~.~~ . In addition~~ to this historical commercial crayfish harvesting~~, DHS occasionally receives calls from citizens who are interested in harvesting crayfish from local waters ~~who~~ and are interested in fish advisory information~~.~~ . According to a member of the Oregon Bass and Panfish club, ~~crayfish~~ traps are placed in the Portland Harbor Superfund Site boundaries and crayfish collected for bait and possibly for consumption (ATSDR 2006)~~.~~ . ~~Even if collection does occur within the Study Area, it is not known whether those crayfish are consumed by humans or used as bait.~~

~~Because site-specific information is not available for shellfish consumption, a range of ingestion rates was evaluated in this BHHRA for adult shellfish consumers.CFor these reasons, consumption of crayfishshellfish was identified in the Programmatic Work Plan to evaluate shellfish consumption in the BHHRA. However, information obtained from other sources indicates that some harvesting of clams within the study area does occur. Thus, consumption of clams was also evaluated as a complete exposure pathway in the BHHRA.~~

~~**3.1.1.2**~~ Although ~~Potentially Complete but Evaluated Under a Different Receptor Category~~

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~~SC~~consumption of shellfish was ~~evaluated as~~considered a potentially complete pathway for ~~could potentially be consumed by~~ dockside workers, in-water workers, recreational beach users, ~~and~~ divers~~.~~, and recreational fishers,~~;~~ ~~Hhowever, as was done for consumption of fish, the consumption of shellfish consumption by these receptors populations is evaluated under the adult shellfish consumer receptor categoryas a separate receptorseparately from fish consumption~~it was quantitatively evaluated only for subsistence fishers~~.~~, as they were considered the most likely population to regularly harvest and consume shellfish.~~.~~

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3.3.7 Infant Consumption of Human Milk

Lipid-soluble chemicals accumulate in body fat, including lipids in breast milk~~.~~. ~~and may be transferred to B~~Breast-fed infants can then be exposed to these chemicals~~.~~. ~~in the lipid portion of human milk, water soluble chemicals also may partition into the aqueous phase and be excreted via human milk. IPer agreement with EPA and DEQ, i~~infant exposure to PCBs, dioxins, DDx compounds, and PDBEs via the consumption of human milk was evaluated as a complete exposure pathway for the children of all receptors. ~~Long-term, ongoing shellfish consumption by transients would not occur; therefore, the adult shellfish consumer receptor category would be protective of shellfish consumption by transients.~~

~~3.1.1.3 Incomplete Exposure Pathways~~

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~~The hypothetical future domestic water use scenario evaluates use of surface water for domestic water supply and thus shellfish consumption was considered an incomplete exposure pathway for this receptor population.~~

~~5.1.6~~3.3.8 Potentially Overlapping Exposure Scenarios

An estimate of reasonable maximum exposure should ~~address~~ not only address exposure for individual pathways, but also ~~Exposure~~ exposures ~~to receptors or populations~~ that ~~can~~ may ~~potentially~~ occur ~~under more than one scenario for an individual~~across multiple exposure routes~~.~~. Examples of ~~these~~ overlapping scenarios include~~:~~ ~~an~~ in-water workers who ~~is also a high-frequency~~fish recreationally, and may also be ~~fisher and~~ recreational beach users~~.,~~ ~~a transient who is also a fisher, a tribal fisher who is also a recreational beach user, and others.~~ P~~The p~~otentially overlapping scenarios are indicated ~~in~~ on ~~Figure~~ Figure 3~~-~~-1~~.~~, and r~~It is likely that one or more of the exposure scenarios potentially affecting an individual will pose a much higher level of risk than the other scenario(s), such that combining the effects of the scenarios will not influence risk management decisions for the Study Area. R~~isks from potentially overlapping scenarios are discussed in Section 5~~ of this~~ the ~~BHHRA~~.

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~~5.2~~3.4 CALCULATION OF EXPOSURE POINT CONCENTRATIONS

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The exposure point concentration (EPC) is defined as the average concentration contacted at the exposure point(s) over the duration of the exposure period (EPA, 1992a). EPA recommends using the average concentration to represent "a reasonable estimate of the concentration likely to be contacted over time" (EPA 1989). Use of the average concentration also coincides with EPA toxicity criteria, which are based on lifetime average exposures~~.~~. Because of the uncertainty associated with estimating the true average concentration at a site, EPA guidance (EPA 1989, 1992) notes that the 95 percent upper confidence limit (UCL) of the arithmetic mean should always be used for this variable~~.~~. ~~Because it is generally not possible to know the true average, the 95 percent upper confidence limit (UCL) of the arithmetic mean (UCL) is typically used in CERCLA risk assessments to represent the average concentration.~~ The UCL is defined as a value that, when calculated repeatedly for randomly drawn subsets of data, equals or exceeds the true population mean 95 percent of the time~~.~~. Use of the UCL can also help account for uncertainties that can result from limited sampling data, and more accurately accounts for the uneven spatial distribution of contaminant concentrations.~~ UCLs were calculated for each analyte using EPA's statistical program ProUCL, Version 4.1 (EPA 2011a) using concentrations directly measured in each~~~~EPCs were calculated for media and pathways that were evaluated quantitatively~~ evaluated ~~in this BHHRA.~~ The process to ~~estimate~~ calculate EPCs for tissue and beach sediment was previously described in the Programmatic Work Plan, and ~~the~~ Round 1 tissue EPCs were previously presented in *Round 1 Tissue Exposure Point Concentrations* (Kennedy/Jenks Consultants 2004b) and *Salmon, Lamprey, and Sturgeon Tissue Exposure Point Concentrations for Oregon Department of Human Services* (Kennedy/Jenks Consultants 2004c), both of which were approved by EPA~~.~~. The process for deriving EPCs for in-water sediment, surface water, and groundwater seeps was previously described in *Exposure Point Concentration Calculation Approach and Summary of*

Exposure Factors (Kennedy/Jenks Consultants 2006), ~~which was approved~~as approved by EPA~~.~~.

EPCs ~~used~~ for RME evaluations ~~were calculated for asare~~represent either the ~~95% percent upper confidence limit on the arithmetic mean (~~95~~%~~ percent UCL,~~)~~ ~~and~~ or the maximum detected value when either there was insufficient data to calculate a UCL or the calculated UCL was greater than the maximum reported value~~.~~. ~~EPA guidance AAHowever, as~~lthough -inconsistent with EPA guidance (EPA 1992), ~~described in DEQ guidance and agreed to by EPA and the LWG,~~ EPCs for ~~theseveral~~sediment and surface water CT~~E~~ evaluations ~~represent~~were calculated as the simple arithmetic- mean~~mean as previously agreed to by EPA and the LWG~~. EPCs for fish/shellfish consumption scenarios are the lesser of the 95 percent UCL or the maximum detected concentration, central tendency evaluations were achieved by using mean or median consumption rates.~~—~~ -For analytes with less than 5 detected concentrations, the maximum detected concentration for that exposure area was used as the EPC for the RME evaluation~~.~~. The uncertainties associated with estimating EPCs from small datasets ~~(i.e., less than 10 detected concentrations)~~ and with using the maximum detected concentration as the EPC are discussed in Section 6~~.~~. The 95 percent UCLs were calculated for each dataset following EPA guidance (EPA 2002a and EPA 2007b)~~.~~. ProUCL version 4.00.02 (EPA 2007b) was used to test datasets for normal, lognormal, or gamma distributions and to calculate the 95 percent UCLs~~.~~. ~~Data were tested first for normality, then for gamma distributions, and finally for lognormal distributions, as recommended by ProUCL guidance (EPA 2007b).~~ If the data did not exhibit a discernable distribution, a non-parametric approach ~~(e.g., Chebyshev)~~ was used to generate a UCL~~.~~. The 95 percent UCLs were calculated using the method recommended by ProUCL guidance (EPA- 2007b) ~~for the data distribution, sample size, and skewness. . n, an. although EPA guidance the arithmetic mean for each exposure area. In some exposure areas, the maximum concentration was used instead of the 95%~~ ~~percent~~ ~~UCL. Therefore, the EPCs are referred to as the 95%~~ ~~percent~~ ~~UCL/max and mean throughout this BHHRA.~~

Prior to calculating EPCs, the ~~for sediment, surface water, tissue, and groundwater seeps,~~ data were ~~reduced~~evaluated~~,~~ ~~as needed,~~ to address reporting of multiple results for the same ~~constituent~~ analyte in the same sample and to reduce laboratory duplicates and field splits of samples to derive ~~one~~ a single value for use~~.~~. Data reductions performed within the SCRA database followed the rules described in *Guidelines for Data Reporting, Data Averaging, and Treatment of Non-Detected Values for the Round 1 Database Technical Memorandum* (Kennedy/Jenks Consultants et al~~.~~. 2004)~~.~~. ~~Additional data reductions and data use rules specific to the BHHRA were approved by EPA and are detailed in Attachment F2.~~

~~Chemicals that were~~Sample results are reported as not detected ~~at~~ when the concentration of the analyte in the sample is less than the detection limit~~.~~. The actual concentration~~s above the detection limit were designated as non-detects. Non-detects may represent concentrations that are~~may be zero~~, or may represent concentrations~~ , or ~~greater than~~some value between zero ~~but less than~~and the detection limit~~.~~. ~~. For purposes of calculating mean EPCs, non-detected values were used in the calculations at one half their detection limit. For both mean CTE and~~N ~~and 95% percent UCL/max~~RME ~~EPCs, non-detects~~s ~~whose for which the detection limit was greater than the maximum detected concentration for in an exposure area were removed from the dataset prior to calculation calculating of the EPCs. For the purposes of~~When ~~calculating 95% percent UCL/max EPCs for the RME evaluations, t~~The following rules were applied to the datasets~~s~~ for tissue ~~(based on species and tissue type)~~, sediment, surface water, and ~~the~~ groundwater seep samples:

1. A~~If a~~ chemical was assumed to not be present if was not detected in any sample for a given medium within the Study Area, ~~it was assumed to not be present, so and~~ an EPC was not calculated for that chemical in that medium

2. A~~If a~~ chemical was presumed to be present if it was detected at least once within the Study Area in samples for a given medium~~, – , the non-detect~~When calculating the 95 percent UCL, non-detects ~~concentrations~~ were used in the calculation ~~in the RME EPC calculations in accordance with the methods used~~ as recommended by ~~in~~ the ~~software~~ ProUCL software. ~~Version 4.00.02 (EPA 2007b).~~ ProUCL software output for the 95~~%~~ percent UCLs calculated in this BHHRA are provided in Attachment F4~~.~~. ~~For purposes of~~When calculating the simple mean~~concentration~~, non-detected values were replaced with one half their detection limit in the calculations.

3. Non-detects for which the detection limit was greater than the maximum detected concentration in an exposure area were removed from the dataset prior to calculating EPCs.

~~2. For purposes of calculating the mean concentration for CT evaluations, non-detected values were used in the calculations at one half their detection limit.~~

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~~In risk characterization, some~~Certain toxicity values are based on exposure to chemical mixtures ~~and not~~rather than to individual chemicals~~. The risks from these chemicals, which~~ , as ~~were~~ identified in *Human Health Toxicity Values Interim Deliverable* (Kennedy/Jenks Consultants 2004a). ~~,~~ Concentrations of the individual isomers or congeners that comprise the mixtures were summed as described in Section 2.2.8 to calculate the EPCs for the mixtures, and the risks from these chemicals were evaluated ~~for the combined exposure to the chemicals and not on an~~on the basis of the combined mixture ~~and not~~rather than ~~to~~for individual chemical~~basis~~s. ~~, and c For chemicals that were evaluated as mixtures in the BHHRA, the concentrations of the individual isomers or congeners that comprise the mixtures were summed to calculate the EPCs for the mixtures, as described in Attachment F2~~. ~~The chemicals evaluated as mixtures are described in Attachment F2 as well, and include: COPCs evaluated as mixtures are PCBs, endosulfans, chlordanes, DDTs, DDDs, DDEs, and 2,3,7,8-TCDD TEQs.~~

~~5.2.1~~3.4.1 Beach Sediment

~~Sediment~~ EPCs for beach sediment were calculated using data collected during Rounds 1 and 2 from locations designated as human use areas during Round 1 and 2, ~~were used to estimate the~~calculate ~~EPCs for beach sediment. There were no additional~~ b~~B~~each sediment data was not collected from human use areas ~~for~~ during Round 3~~.~~. ~~Within the Study Area, EPCs were estimated for exposure areas based on the different types of potentially exposed populations potentially exposed. Since potentially complete exposure pathways for sediment involve direct contact with beach sediments, only beach sediment data were used in estimating EPCs for direct exposure pathways.~~

One composite sample was collected from each beach area~~.~~, and ~~Therefore,~~ the results from ~~the~~ each composite sample were was ~~used for both the 95% percent UCL/max and~~as ~~the mean~~ as the EPC~~s~~ for the ~~both the~~ RME and CT evaluations~~s.~~~~that beach. The process to estimate EPCs for each receptor population is described below.~~

~~5.2.1.1 Dockside Workers~~

~~15.0 Dockside workers could potentially be exposed to beach sediment in areas considered to be industrial sites as dockside worker use areas, which are shown in on Map 2-1, and b. Beach sediment data from each of these areas were used to estimate the EPCs for dockside workers. For dockside workers, the exposure area is considered to be the industrial site (i.e., facility within a property boundary) where the worker is employed. To estimate an EPC for each~~When evaluating exposure for dockside workers at industrial sites, the same EPC was used to represent adjacent sites ~~beach sediment data from the composite sample collected from the beach associated with that industrial site were used. If~~in instances where the beach area ~~extends~~ extended across ~~multiple~~ individual ~~industrial~~ site boundaries~~s, the same EPC was used to evaluate exposure of dockside workers at each of the adjacent industrial sites. Beach sediment EPCs in beach sediment for the exposures of dockside workers worker scenario are presented in Table 3-2.~~. Otherwise, each designated beach area was evaluated as a single exposure area for transients, recreational beach users, and recreational/subsistence~~/~~ and tribal fishers~~.~~. Beach sediment exposure areas are presented on Map 2-1, EPCs for dockside workers are presented in Table 3-2, EPCs for transient, recreational, and fishing uses are presented in Table 3-3.

~~5.2.1.2 Transients~~

~~Transients could potentially be exposed to beach sediment in areas where such use is known or suspected to occur. transient use areas, which are While some individuals may move throughout the Study Area, others may spend a majority of their time at a single location. Accordingly, EPCs for transients were estimated for each individual beach area as shown in on Map 2-1, and . Transients may move throughout the Study Area, while some may spend a majority of their time at only one of the identified areas. Therefore, EPCs for transients were estimated for each beach area within the~~

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~~transient use areas to represent a range of possibilities for transients residing in the Study Area. Beach sediment EPCs for exposures by transients are presented in Table 3-3.~~

~~5.2.1.3 Recreational Beach Users~~

~~Recreational beach users could potentially be exposed to beach sediment in areas designated as having the potential for recreational use. These area may be accessed by the public either directly from the shore, or via boat. e areas For recreational beach users, the exposure areas were evaluated as a single beach, although individuals may be exposed to multiple beach areas within the Study Area during the exposure time period. , which are shown in Map 2-1. Beach sediment data from these areas were used to estimate the the EPCs for each individual beach area as shownEPCs for recreational beach users. For recreational beach users, the exposure area is considered to be one river beach area, which represents a conservative assumption for the BHHRA because the beach user could be exposed to multiple recreational beach areas within and outside of the Study Area during the exposure time period. EPCs were estimated for individual beaches within the recreational beach use areas. Beach sediment EPCs for exposures by recreational beach users are presented on Map 2-1, the specific EPCs are presented in Table 3-3.~~

~~5.2.1.4 Fishers~~

~~Fishing from shore could occur from beaches with unrestricted access, which are were considered to be the same locations as potential transient and/or recreational use areas. Although recreational and subsistence fishers may fish from multiple beach areas within the Study Area, exposures for fishers were evaluated at individual beaches in order to provide a range of risk estimates for individual beaches throughout the Study Area. Because fishing was assumed to occur at the same beach areas as evaluated for the recreational and transient use areas, the same EPCs calculated for transients and recreational beach users were used Beach sediment data from these areas were used to estimate the EPCs for non-tribal and tribal fishers, as shown on Map 2-1. Fishers are likely to fish from multiple beach areas within and outside of the Study Area during the exposure time period. The exposure area for fishers was considered to be one individual beach in order to provide a range of risk estimates for individual beaches within the Study Area. EPCs were estimated for individual beaches within the recreational and transient use areas and are the same as the EPCs for transients and recreational beach users. Beach sediment EPCs for beach sediment exposures by to fishers are presented in Table 3-3.~~

~~5.2.2~~3.4.2 In-Water Sediment

~~In-water sediment data of appropriate data quality collected within the Study Area were used to estimate EPCs for in-water sediment.~~ Direct contact with in-water sediment ~~would only~~ is most likely to occur ~~with~~ in the near-shore areas outside of the navigation channel~~—~~. ~~surface sediment~~T~~,~~ ~~so~~ thus, only surface sediment data collected ~~(~~less than 30.5 cm in depth and~~)~~ ~~collected~~ outside of the navigation channel

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were used ~~in~~ to ~~estimating the EPCs~~ ~~for~~ exposure to in-water sediment ~~exposures.~~ . ~~Exposure to in-water sediment was assumed to be a complete pathway~~

~~If a contaminant was detected at least once in surface sediment within the Study Area, an EPC was calculated for that contaminant, and any non-detect concentrations were included in the EPC calculations in accordance with the ProUCL Version 4.00.02 guidance (EPA 2007b). In-water sediment EPCs were estimated for in-water workers, fishers, and divers, and the calculated and EPCs are presented in Table 3-4.~~

~~**5.2.2.1** In-Water Workers~~

~~Exposure For in-water workers, to sediment exposure by in-water workers could occur anywhere within the Study Area that docks or pilings are being constructed or where other in-water activities are occurring (, such as maintenance dredging of private slips or berths). While these activities would not necessarily be restricted to a given area, exposure would most likely be localized to in-water sediment adjacent to facilities where these activities occurat specific facilities. Most of these activities would be, and between the shore and the navigation channel. As a resultAccordingly, near-shore sediment samples, s in near-shore (i.e., excluding the central navigation channel)~~ Iin—water sediment EPCs are calculated in one-~~-~~half- ~~river~~ mile segments along both sides of the river ~~were used to develop EPCs for in-water sediment EPCs. . In addition to calculating EPCs for exposure within the Study Area, EPCs they were also calculated for the downstream reach of the river~~ from ~~RM~~ RM 1.0 to RM ~~—1.9, the downtown reach of the river from RM RM 11.8~~ —12.2, and for samples within Multnomah Channel~~, per an agreement with EPA.~~ .

~~In accordance with EPA guidance (1989), the 95% percent UCL was used for the 95% percent UCL/max EPC for in-water workers for exposure areas with at least 5 detected concentrations for a given analyte. For analytes with less than 5 detected concentrations, the maximum detected concentration for that exposure area was used as the 95% percent UCL/max EPC. Uncertainties associated with estimating EPCs for small datasets (i.e., less than 10 detected concentrations) and in using the maximum detected concentration as the EPC are discussed in Section 6. The arithmetic mean of detected concentrations was used for the mean EPC. The 95% percent UCLs were calculated for each dataset following EPA guidance (EPA 2002a and EPA 2007b). ProUCL version 4.00.02 (EPA 2007b) was used to test datasets for normal, lognormal, or gamma distributions and to calculate the 95% percent UCLs. Data were tested first for normality, then for gamma distributions, and finally for lognormal distributions, as recommended by ProUCL guidance (EPA 2007b). If the data did not exhibit a discernable distribution, a non-parametric approach (e.g., Chebyshev) was used to generate a UCL. The 95% percent UCLs were calculated using the method recommended by ProUCL guidance (EPA 2007b) for the data distribution, sample size, and skewness.~~ In-water sediment EPCs for exposures by in-water workers, divers, and recreational/subsistence/tribal fishers are presented in

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3--4.

~~5.2.2.2 Fishers~~

~~Fishers include adult non-tribal and tribal fishers. The fisher scenario is based on long-term exposure. Although rFor repeated exposures with in-water sediment over an entire lifetime, direct contact with in-water sediment wouldmay occur over a very wide area. Even though exposure would occur over a wide area, in-water sediment EPCs for the fishers were derived on a half-mile segments on each side of the river, as was done for the in-water workers, as requested by EPA in its comments, dated February 24, 2005 on the draft *Exposure Point Concentration Calculation Approach and Summary of Exposure Factors*. Deriving exposure areas based on a half-mile segment on each side of the river provides a range of possibilities for risk management and for risk communication to fishers making fishing location choices. In addition to calculating EPCs for exposure within the Study Area, EPCs were also calculated for the downstream reach of the river from RM 1.0 – 1.9, the downtown reach of the river from RM 11.8 – 12.2, and for samples within Multnomah Channel, per an agreement with EPA. Both the mean and 95% percent UCL/max EPCs were calculated as described for the in-water worker EPCs. In-water sediment EPCs for exposures to fishers are presented in Table Table 3 -4.~~

~~5.2.2.3 Divers~~

~~Commercial divers could conductmay be involved in diving activities anywhere within the Study Area, although exposure to in-water sediment would most likely be to in-water sediment adjacent to facilities where commercial diving is required for purposes such as marine construction, underwater inspections, and routine operations and maintenance. It is assumed that all other diving done by a diver is done outside of the Study Area. Accordingly, iTherefore, in-water sediment EPCs for the diver scenario were derived for half-mile segments on each side of the river, as was done for the in-water workers, and as directed by EPA in the its memorandum dated September 15, 2008 (EPA 2008c). In addition to calculating EPCs for exposure within the Study Area, EPCs were also calculated for the downstream reach of the river from RM 1.0 – 1.9, the downtown reach of the river from RM 11.8 – 12.2, and for samples within Multnomah Channel, per an agreement with EPA. Both the 95% percent UCL/max and mean EPCs were calculated as described for the in-water worker EPCs. In-water sediment EPCs for exposures to divers are presented in Table Table 3-4.~~

~~5.2.3~~3.4.3 Surface Water

Exposure concentrations in s~~S~~urface water were calculated using data ~~cof appropriate data quality c~~ollected within the Study Area~~-~~, as well as the transect data collected from the mouth of Multnomah Channel~~were used to estimate EPCs. ~~ . Both integrated and non-integrated water column ~~surface water~~ samples ~~were collected within the~~

~~Study Area and~~ were ~~used~~included in the data set, the s~~ in estimating the surface water EPCs. SThe s~~pecific samples used ~~to estimate EPCs for each receptor~~ were dependent upon the anticipated exposures by the different receptors~~ of that receptor to surface water within the Study Area.~~ . ~~Surface water EPCs were estimated for transient, recreational beach user, diver, and hypothetical future domestic water user exposure scenarios, and aA summary of surface water~~the samples used to calculate ~~EPCs for each receptor is provided in Table 3-5. Surface water EPCs were estimated for transient, recreational beach user, diver, and hypothetical future domestic water user exposure scenarios.~~

~~5.2.3.1~~ ~~SBecause surface water e~~Transients

Exposures by transients ~~tTransient exposures to surface water could~~may occur throughout the year~~ at transient use areas within the Study Area. As a result,~~For this reason, ~~data~~ EPCs were calculated using data from all seven ~~of the completed~~ seasonal sampling events~~ were used.~~–. The data from– each of the five transect locations were combined as described in Section- 2.2.6. and EPCs were calculated for those five locations, at Willamette Cove using the discrete ~~in estimating the surface water EPCs for transients. Data from the four transect stations within the Study Area were used to estimate surface water EPCs for~~ evaluating exposures ~~at~~ to transients ~~use areas throughout the Study Area. Results~~ s~~of near-bottom and near-surface horizontally integrated transect samples from the same sample location and sampling event were combined prior to calculation of EPCs, as were vertically integrated transect samples from the east, middle, and west portions of the river. Rules for combining transect samples are described in Attachment F2. S~~urface water ~~samples~~ samples, and on a ~~Harbor~~Study Area-wide basis using the combined transect data from within the Study Area, excluding the transect location W027, which was collected at the mouth of Multnomah Channel~~were also collected at Willamette Cove, which is a quiescent transient use area that may not be adequately characterized by the transect samples. Year-round data from this surface water sample location were used to estimate surface water EPCs for exposures in Willamette Cove.~~ . Surface water EPCs for exposures by transients are presented in ~~Table~~ Table 3-~~-~~6.

~~Given that transients can~~ may ~~live along many parts of the river, EPCs were calculated for each transect, as well as for the combination of all four transects. In addition to calculating EPCs for exposures within the Study Area, EPCs were calculated for one transect station outside of the Study Area, at Multnomah Channel. For the 95%~~ percent ~~UCL/max EPC, the 95%~~ percent ~~UCL was used for the EPC for exposure areas with at least 5 detected concentrations for a given analyte. For analytes with less than 5 detected concentrations in a given exposure area, the maximum detected concentration was used as the EPC. Uncertainties associated with estimating EPCs for small datasets (i.e., less than 10 detected concentrations) and in using the maximum detected concentration as the EPC are discussed in Section 6. The 95%~~ percent ~~UCLs were calculated as described for in-water sediment. The arithmetic mean of the detected concentrations for each exposure area was used for the mean EPC.~~

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~~5.2.3.2 Recreational Beach Users~~

~~Recreational beach user Eexposures to SEBecause~~ exposure to ~~s~~surface water by recreational beach users ~~at recreational use areas within the Study Area could is largely expected~~was assumed to occur primarily during summer months ~~at recreational use areas within the Study Area. The only summer sampling event for recreational use areas occurred in July 2005. As a result. Accordingly,~~. Therefore, ~~,~~ only data from the low-water sampling event conducted in July 2005 ~~that sampling event~~ were used ~~in~~ for ~~estimating~~ calculating the surface water EPCs ~~for recreational beach users.~~ . ~~The uncertainty associated with using data from only the low-water summer sampling event is discussed further in Section 6. D~~These data were collected from recreational beaches in July 2005 included three transect locations and three single-point locations (Cathedral Park, Willamette Cove, and Swan Island Lagoon)~~.~~. ~~Data from the three transect stations (W005, W011, W023) were used to estimate surface watercalculate EPCs for representing exposures at non-quiescent recreational beach use areas throughout the Study Area, and data from the three single-point surface water samples sample locations were used to estimate calculate EPCs for to represent exposure at quiescent recreation beach areas. . Because only one sample was collected from each quiescent area during low-water periods, the results for the single sample were used as both the 95% percent UCL/max EPC and the mean EPCs for each area. Only three transect samples were collected in July 2005 during the low-water period, so the maximum concentrations were used as the 95% percent UCL/max EPCs and the arithmetic mean of detected concentrations were used as the mean EPCs.~~ Surface water EPCs for exposures by recreational beach users are presented in ~~Table~~ Table 3-~~-~~7.

~~5.2.3.3 Divers~~

~~Diver E~~Exposures to surface water by divers ~~could was~~were assumed to occur throughout ~~the year at all areas within~~ the Study Area and ~~was~~were not considered seasonally dependent~~.~~. ~~Therefore, for divers, all of the surface water data collected in the Study Area, including both transect data and data collected from single point stations, were used to estimate EPCs. In addition to calculating EPCs for exposure within the Study Area, EPCs were also calculated for one transect station outside of the Study Area, at Multnomah Channel. Transect data were used to estimate EPCs for diver exposures as described for transient exposures (Section 3.4.3.1). Surface water data available as single point samples from Round 2 in several areas of the Study Area, and as near-bottom and near-surface samples from Round 3 sampling, were also used to estimate EPCs. For the Round 3 surface water samples collected as single point samples, the near-bottom and near-surface samples were combined for use in estimating EPCs, as described in Attachment F2. As with diver exposure to in-water sediment, diver exposure to surface water is expected to be in localized areas adjacent to facilities where commercial diving is required for purposes such as marine construction, underwater inspections, and routine operation and maintenance. Therefore, samples from single point stations were used to calculate EPCs for near-shore half-river mile segments along both sides of the river, consistent with the~~

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~~approach for in-water sediment EPCs and per direction from EPA.~~EPCs were calculated in one-half mile intervals along each side of the river, and at each transect location~~. –~~. ~~Surface water~~ EPCs in surface water for exposures by divers are presented in ~~Table~~ Table 3~~-~~-8.

~~5.2.3.4 Domestic Water User~~

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U~~The hypothetical u~~se of ~~untreated~~ surface water as a domestic water source ~~could~~ was assumed to have the potential to occur ~~within~~ at any location through the Study Area ~~throughout the year~~on a year-round basis~~. –~~. ~~As a result~~Accordingly, data from all seven ~~of the completed~~ seasonal sampling events were used ~~in estimating the surface water EPCs for the domestic water user. –~~. EPCs were ~~determined~~ calculated for all individual transect stations and for single point stations with vertically integrated ~~samples~~data~~. This dataset included samples from the four transect stations within the Study Area and single point vertically integrated samples from Cathedral Park, Willamette Cove, and Swan Island Lagoon. In addition, EPA required that data from, –~~. In addition, data from locations where co-located near-bottom and near-surface ~~surface water stations where both~~ samples were collected ~~be~~ were averaged and used in the domestic water dataset. Study Area-wide EPCs included all vertically integrated samples~~. –~~. ~~Transect data were used to estimate EPCs for hypothetical domestic water use as described for transient exposures (Section 3.4.3.1). For~~ ~~At single point stations, fewer than five samples were taken from each station, so the maximum detected concentration was used as the 95% percent UCL/max EPCfor the RME evaluation and the mean of detected concentrations was used as the mean Efor CTPC. Surface water EPCs were estimated for transient, recreational beach user, diver, and hypothetical future domestic water user~~ ~~Surface water~~ EPCs ~~in surface water~~ for~~–~~ the ~~hypothetical~~ use of ~~untreated~~ surface water as a domestic water source are presented in ~~Table~~ Table 3~~-~~-9.

~~5.2.4~~3.4.4 Groundwater Seeps

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As discussed Section 2.1.4, Outfall 22B, which is located on the west side of the river at ~~RM~~ RM 7, was the only seep identified ~~Direct contact with groundwater would occur only within human use areas where groundwater comes to the surface (i.e., seeps) on the beach above the water line. Each Thus, each groundwater seep where direct contact could occur represents an exposure area for this pathwayfor groundwater. The only groundwater seep~~ where direct contact could occur within the Study Area~~. –~~. Data from two sampling events ~~is within the potential transient use area located on the west side of the river at RM 7 (Map 2-5) at . Outfall 22B., which is a potential conduit of groundwater discharge and results in the water present on that beach, was sampled twice~~ between 2002 and 2007 at times that did not involve stormwater influence~~. If a chemical was detected in only one of the two samples, that the result for that contaminant was used as both the 95% percent UCL/max and mean EPCsas the EPC for both RME and CT evaluations for that contaminant. If a contaminant was detected in both samples, the maximum concentration was used as~~

~~the 95% percent UCL/max EPC for the RME evaluation, and the arithmetic mean of the detected concentrations was used as the mean EPC. For the CT evaluation. Groundwater seep~~~~These~~ were used to calculate the ~~EPCs~~ EPC, and the results are presented in ~~Table~~ Table 3-~~-~~10.

~~5.2.5~~3.4.5 Fish and Shellfish Tissue

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EPCs ~~Fish~~ for fish and shellfish tissue ~~EPCs~~ were ~~derived~~ calculated ~~from~~ using ~~tissue sampling results~~data collected in ~~of~~ the ~~the LWG~~ Round- 1, ~~Round~~ Round 2, and ~~Round~~ Round 3 investigations, and the ODHS study~~. –~~. ~~Fish tissue EPCs are presented in Tables 3-11 through 3-21, and shellfish tissue EPCs are presented in Tables 3-22 though 3-25. The~~ EPCs derived from Round 1 data were originally presented in *Round 1 Tissue Exposure Point Concentrations* (Kennedy/Jenks ~~Consultants~~ Consultants 2004b)~~, which was approved by EPA.~~ . EPCs derived using the results of the ODHS study were originally presented in *Salmon, Lamprey, and Sturgeon Tissue Exposure Point Concentrations for Oregon Department of Human Services* (Kennedy/Jenks Consultants 2004c).~~These EPCs were derived for fish species and crayfish that were evaluated for human consumption. Since Round 1, new additional data have been collected for clam, crayfish, smallmouth bass, and common carp. No new additional data have been collected since Round 1 for use in the calculation of brown bullhead and black crappie EPCs. The EPCs derived for adult salmon, adult lamprey, and adult sturgeon using the results of the ODHS study were originally presented in~~ ~~*Salmon, Lamprey, and Sturgeon Tissue Exposure Point Concentrations for Oregon Department of Human Services*~~ ~~(Kennedy/Jenks Consultants 2004c). These EPCs were derived calculated for salmon whole body, fillet with skin, and fillet fillet without without skin composite samples, lamprey whole body composite samples, and sturgeon fillet fillet without without skin samples.~~

~~Crayfish and clams were collected and composited at each sampling location. EPCs for crayfish were calculated for crayfish at individual locations , as well as for the entire Study Area per the Programmatic Work Plan. EPCs for clams were calculated for clams for approximately one river mile on each side of the river, as well as for the entire Study Area, as required by EPA in its comments on the Round 2 Report. EPCs were also calculated for crayfish and clams collected between RM 1.0 and 1.9 and between RM 11.8 and 12.2, per an agreement with EPA. EPCs for clams were calculated for both depurated and undepurated samples.~~

Smallmouth bass were collected and composited over a per river mile~~. –~~. EPCs—whole body and fillet—were calculated for smallmouth bass at each ~~per~~ river mile as well as for the entire Study Area consistent with their small home range~~, as specified in~~ ~~per the Programmatic Work Plan.~~ . ~~EPCs were calculated for both whole body and fillet samples.~~

Common carp, black crappie, and brown bullhead were collected and composited within river segments designated as fishing zones, which are largely based ~~based in part~~ on the home range of the fish as determined in a study of anadromous fish in the LWR by the Oregon Department of Fish and Wildlife (ODFW 2005)~~. ~~. ~~For~~ Fishing zones in ~~Round~~ Round 1 ~~consisted of two data collection, there were two fishingthree mile long fishing zones zones that extended over~~were designated three-mile segments~~:~~ at ~~RM RM~~ RM 3--6 and ~~RM RM~~ RM 6--9~~.~~. ~~For~~ Round- 3~~, which data collection, -which~~ included additional samples of common carp ~~(only, collection~~ but not black crappie or brown bullhead)~~, there were and was divided in to~~from three separate four mile long fishing zones that extended over four-mile segments ~~:~~at ~~RM RM~~ RM 0--4, ~~RM RM~~ RM 4--8, and ~~RM RM~~ RM 8--12~~.~~. EPCs -for common carp, black crappie, and brown bullhead were calculated as whole body and fillet for each fishing zone ~~in~~ from which they were sampled,~~,~~ as well as for the ~~entire sampling area to representthe entire~~ Study Area~~-wide exposure.~~ . ~~EPCs were calculated for both whole body and fillet samples.~~

Adult salmon ~~and lamprey~~ were collected at the Clackamas fish hatchery, ~~and Willamette Falls, respectively,~~ adult lamprey were collected at Willamette Falls, and sturgeon were collected ~~at various locations~~ throughout the Study Area~~.~~. Salmon were analyzed as whole body, fillet with skin, and fillet without skin composite samples~~.~~. Lamprey were analyzed only as whole body composite samples, sturgeon were analyzed only as fillet without skin composite samples~~.~~. EPCs were calculated for each species accordingly as average concentrations representative of the entire Study Area.

Crayfish and clams were collected and composited at each sampling location~~.~~. EPCs for crayfish were calculated for each individual location as well as for the entire Study Area~~.~~. EPCs for clams were calculated for both depurated and undepurated samples per river mile on each side of the river, as well as for the entire Study Area~~.~~. EPCs were also calculated for crayfish and clams collected between RM- 1.0 and 1.9 and between RM- 11.8 and 12.2, per an agreement with EPA.

EPCs for fish tissue are presented in Tables- 3--11 through 3--21, and EPCs for shellfish tissue are presented in Tables- 3--22 through 3--25. ~~EPCs representative of the entire Study Area were calculated for adult salmon, adult lamprey, and sturgeon using available data to be representative of theas follows: entire Study Area. adult salmon, EPCs were calculated for both whole body and fillet; adult lamprey, whole body; and sturgeon, fillet onlysamples for adult salmon. Only whole body data were available for adult lamprey and only fillet data were available for sturgeon, so the EPCs for adult lamprey were calculated for whole body samples and the EPCs for sturgeon were calculated for fillet samples.~~

~~In calculating the EPCs for fish and shellfish, if only one sample was collected within a given exposure area, that result was used as both the 95% percent~~

~~UCL/max and mean~~ RME and CTE ~~EPC for that contaminant. If more than one sample was collected, either the 95%~~ percent ~~UCLs or~~ the ~~maximum~~ detected ~~concentrations were~~ was ~~used as the 95%~~ percent ~~UCL/max~~RME ~~EPCs, depending on the number of reported concentrations~~detections~~. If detected concentrations for at least five samples were available, the 95%~~ percent ~~UCLs were calculated as described for in-water sediment. If less than five detected concentrations were available, the maximum detected concentration was used as the 95%~~ percent ~~UCL/ max EPC. EPCs for Study Area-wide exposure were calculated from the Study Area-wide data set. Uncertainties associated with estimating EPCs for small datasets (i.e., less than 10 detected concentrations) and in using the maximum detected concentration as the EPC are discussed in Section 6. The arithmetic mean of detected concentrations was used as the mean EPC, assuming that all non-detects were one-half the detection limit.~~

~~EPCs for multi-species fish~~ diet ~~tissue consumption scenarios were calculated using a weighted average of site-wide EPCs for each COPC, based on the percent of each species consumed in the diet.~~

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~~5.3~~3.5 ~~PROCESS TO CALCULATE~~ESTIMATION OF CHEMICAL INTAKES

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The amount of each chemical incorporated into the body is defined as the dose and is expressed in units of milligrams per kilogram per day (mg/kg-day)~~–~~. The dose is calculated differently when evaluating carcinogenic effects than when evaluating noncarcinogenic effects~~.–~~. Each is described below:

~~Noncarcinogens~~Non-cancer effects:– The dose is averaged over the estimated exposure period~~.–~~. ~~This is done to be consistent with the assumption that adverse effects are not expected occur after exposure has ceased.~~ Thus, the ADD is used to represent the potential for adverse health effects over the period of exposure.

~~Carcinogens~~Carcinogenic effects:– The dose is based on the estimated exposure duration, extrapolated over an estimated 70-year lifetime~~.–~~. This is consistent with the cancer slope factors, which are based on lifetime exposures, and on the assumptions that the risk of carcinogenic effects is cumulative and continues even after exposure has ceased.

For non-occupational scenarios where exposures to children ~~are also expected to be present~~are considered likely, both adult and child receptors were evaluated. ~~because~~ C~~c~~hildren often exhibit behavior such as outdoor play activities and greater hand-to-mouth contact~~,~~ that can result in greater exposure than for a typical adult. In addition, children also have a lower overall body weight relative to the predicted intake. Because cancer risks ~~is~~are averaged over a lifetime, ~~it~~they ~~is~~are directly proportional to the exposure duration as well as the dose and the potency of the chemical. Accordingly, cancer risks were also assessed for a combined exposure from childhood through adult years, to account for the increased relative exposure and susceptibility associated with childhood exposures.

Superfund exposure assessments should be conducted such that the intake variables for an exposure pathway should result in an estimate of the reasonable maximum exposure (RME) expected to occur under both current and future land use conditions (EPA, 1989)~~.~~. The RME is defined as the highest exposure that is reasonably expected to occur at a site~~.~~. The intent is to estimate an exposure that is substantially greater than the average, yet is still within the range of possible exposures~~.~~. In general, this is accomplished by using a combination of 90th or 95th percentile values for contact rate, exposure frequency and duration, and 50th percentile values for other variables~~.~~. This BHHRA also evaluated central tendency (CT) exposures, which is intended to represent an average exposure by the affected population~~.~~. ~~EPA (1989) defines exposure as "the contact with a chemical or physical agent" and defines the magnitude of exposure as "the amount of an agent available at human exchange boundaries (i.e., the lungs, gut, and skin) during a specified time period." Exposure assessments are designed to determine the degree of contact a person has with a chemical. Thus, estimating human exposure to a chemical requires information regarding the concentration of the chemical in the environmental media (sediment, water, tissue) with which a person will come into contact and the extent of contact the person will have with the media.~~

~~Chemical-specific intake or dose was quantified in this BHHRA by estimating the chronic daily intake (CDI) for noncarcinogens, or the lifetime average daily intake (LADI) for carcinogens. CDI and LADI, expressed in terms of the mass of substance taken into the body per unit body weight per unit time (mg/kg/day), were calculated using equations based on exposure parameters that represent the duration of exposure, frequency of exposure, and other factors that affect overall chemical dose. Consistent with EPA guidance (1989), exposure assessments were based on the RME expected to occur under both current and potential future land use conditions, as well as hypothetical future conditions. Exposure assessments using CT values, which are more representative of average exposures, were also conducted.~~ Rationale and/or references for each of the RME and CT values for exposure pathways that were quantitatively assessed for each exposure scenario for different populations are presented in exposure factor Tables 3-26 through 3-30 and discussed in the following sections.

3.5.1 Incidental Ingestion of ~~Soil and~~ Sediment

The following equation was used to calculate the intake (expressed as milligrams per kilogram per day [mg/kg-day]) associated with the incidental ingestion of contaminants in soil or sediment:

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$$CDI / LADI = \frac{C_s \times IRS \times 10^{-6}\, kg/mg \times EF \times ED}{BW \times AT}$$

Age-weighted exposures for the combined child and adult receptors were calculated using the following equations:

$$CDI / LADI = \frac{C_s \times IFS_{adj} \times EF \times 10^{-6}\, kg/mg}{AT}$$

where:

$$IFS_{adj} = \frac{ED_c \times IRS_c}{BW_c} + \frac{ED_a \times IRS_a}{BW_a}$$

where:

C_s = chemical concentration in soil or sediment (mg/kg)
IFS_{adj} = age-adjusted soil/sediment ingestion factor [(mg-year)/(kg-day)]
IRS_a = adult soil/sediment ingestion rate (mg/day)
IRS_c = child soil/sediment ingestion rate (mg/day)
EF = exposure frequency (days/year)
ED_a = adult exposure duration (years)
ED_c = child exposure duration (years)
BW_a = adult body weight (kg)
BW_c = child body weight (kg)
AT = averaging time (days)

The exposure assumptions for estimating chemical intake from the ingestion of chemicals in ~~soil and~~ sediment are provided in Tables 3-26 and 3-27~~-~~.

3.5.2 Dermal Contact with ~~Soil or~~ Sediment

The following equation was used to calculate ~~the intake~~exposure resulting from dermal contact with contaminants in soil or sediment:

$$CDI / LADI = \frac{C_S \times ABS \times SA \times AF \times EF \times ED \times 10^{-6}\, kg/mg}{BW \times AT}$$

Combined child and adult a~~The following~~ age-weighted ~~equation~~exposures resulting from~~ was used to calculate the intake from~~ dermal contact with contaminants in sediment for the recreational beach user exposure scenarios:

$$CDI / LADI = \frac{C_S \times SFS_{adj} \times ABS \times EF \times 10^{-6}\, kg/mg}{AT}$$

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where:

$$SFS_{adj} = \frac{ED_c \times AF_c \times SA_c}{BW_c} + \frac{ED_a \times AF_a \times SA_a}{BW_a}$$

where:

C_s -= chemical concentration in soil or sediment (mg/kg)
SFS_{adj} = -age-adjusted dermal contact factor [(mg-year)/(kg-day)]
ABS = absorption efficiency
SA_a = adult exposed skin surface area (square centimeters [cm^2])
SA_c = child exposed skin surface area (cm^2)
AF_a = adult soil-to-skin adherence factor (mg/cm^2)
AF_c = child soil-to-skin adherence factor (mg/cm^2)
EF = exposure frequency (days/year)
ED_a = adult exposure duration (years)
ED_c = child exposure duration (years)
BW_a = adult body weight (kg)
BW_c = child body weight (kg)
AT = -averaging time (days)

The exposure assumptions for estimating exposure from dermal contact with soil or sediment are provided in Tables 3-26 and 3-27-. ~~Dermal absorption factor values were obtained from EPA 2004.~~

Dermal absorption of chemicals from soil or sediment adhered to the skin is dependent on a variety of factors, including the condition of the skin, the nature of adhered soil/sediment, and the chemical concentration~~.~~ . Dermal absorption factors, representing the fraction of a chemical absorbed from soil or sediment adhered to the skin, are presented in Table 3-31~~.~~ . Only those compounds or classes of compounds for which dermal absorption factors are presented were evaluated quantitatively via dermal contact, although assuming less than complete absorption may not fully describe risks associated with dermally active compound such as carcinogenic PAHs~~.~~ . The uncertainties associated with the exposure and risk estimates via dermal exposures with soil and sediments are presented in Section 6.

3.5.2.1 -Ingestion of Surface Water

~~The following age-weighted equation was used to calculate intake associated with the ingestion of groundwater or surface water~~Exposure resulting from ingestion of surface water was evaluated using the following equation:

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$$CDI / LADI = \frac{C_w \times IR_w \times EF \times ED \times 10^{-6}\ kg/mg}{BW \times AT}$$

Combined child and adult age-weighted exposures due to ingestion of surface water were calculated as follows:

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$$CDI / LADI = \frac{C_w \times IFW_{adj} \times EF}{AT}$$

where:

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$$IFW_{adj} = \frac{ED_c \times IRW_c}{BW_c} + \frac{ED_a \times IRW_a}{BW_a}$$

where:

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C_W = chemical concentration in water (mg/L)
IFW_{adj} = age-adjusted water ingestion factor [(L-year)/(kg-day)]
IRW_a = adult groundwater ingestion rate (L/day)
IRW_c = child groundwater ingestion rate (L/day)
EF = exposure frequency (days/year)
ED_a = adult exposure duration (years)
ED_c = child exposure duration (years)
BW_a = adult body weight (kg)
BW_c = child body weight (kg)
AT = averaging time (days)

The exposure assumptions for estimating chemical intake from the ingestion of groundwater or surface water are provided in Tables 3-28 and 3-30.

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3.5.3 Dermal Contact with Surface Water

~~The~~ Dermal absorption of contaminants due to direct contact with surface water was evaluated using the following equation~~ was used to calculate the dose associated with dermal contact with surface water~~:

$$CDI / LADI = \frac{DA_{event} \times EV \times EF \times ED \times EF \times SA}{AT \times BW}$$

The combined child and adult a~~The following a~~ge-weighted ~~equation~~exposure was ~~used to calculate the intake associated with dermal contact with surface water or surface water~~calculated as follows:

$$CDI / LADI = \frac{C_w \times SFW_{adj} \times K_p \times EF \times ET \times CF}{AT}$$

where:

$$SFW_{adj} = \frac{ED_c \times SA_c}{BW_c} + \frac{ED_a \times SA_a}{BW_a}$$

Where:

C_{ww} = chemical concentration in water (mg/L)
DA_{event} = dermally absorbed dose (mg/cm^2-event)
SFW_{adj} = age-adjusted water dermal contact factor [(cm^2-year)/kg]
K_p = dermal permeability coefficient (cm/hour)
EF = exposure frequency (days/year)
ET = exposure time (hour)
CF = Conversion Factor (0.001 L/cubic centimeter)
ED_a = adult exposure duration (years)
ED_c = child exposure duration (years)
SA_a = adult exposed skin surface area (cm^2)
SA_c = child exposed skin surface area (cm^2)
BW_a = adult body weight (kg)
BW_c = child body weight (kg)
AT = averaging time (days)

~~One of the parameters in the intake equations for dermal contact with surface water or groundwater seeps is the~~The absorbed dose per event (DA_{event})~~.~~ . ~~This parameter was derived~~ for assessing direct contact with water ~~per~~ was calculated ~~EPA guidance (2004)~~ using the chemical-specific factors~~, which are~~ presented in Tables 3-32 ~~for scenarios involving direct contact with surface water or groundwater seeps and in Table~~and 3-33 ~~for the hypothetical domestic water use scenario.~~. These ~~chemical-specific factors used in the calculation of DA_{event}~~ values were obtained from Appendix B ~~(Screening Tables and Reference Values for the Water Pathway)~~ of EPA's Supplemental Guidance for Dermal Risk Assessment (2004)~~.~~. The uncertainties associated with calculating DA_{event} for chemicals with factors outside of the predictive domain are discussed in Section 6.

3.5.4 Consumption of Fish/Shellfish

~~To evaluate the potential for risk to human consumers of fish (i.e., recreational anglers), site-specific fish tissue data were used.~~ The following equation was used to estimate ~~chemical intake~~exposure associated with the consumption of fish and shellfish:

$$CDI / LADI = \frac{C_t \times IR \times 10^{-3} kg/g \times EF \times ED}{BW \times AT}$$

Combined child and adult exposure was evaluated using the following equation:

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$$CDI/LADI = \frac{C_t \times IR_{t-adj} \times 10^{-3}\,kg/g \times EF}{AT}$$

where:

$$IR_{t-adj} = \frac{ED_c \times IR_c}{BW_c} + \frac{ED_a \times IR_a}{BW_a}$$

where:

C_t = Contaminant concentration in fish tissue (mg/kg, wet-weight basis)
IR_{tc} = Fish ~~ingestion~~consumption -rate - child (g/day, wet-weight basis)
IR_a = Fish consumption rate - adult (g/day, wet-weight basis)

EF = Exposure frequency (days/year)
ED_c = Exposure duration – child (years)
ED_a = Exposure duration – adult (years)
BW_c = Body weight – child (kg)
BW_a = Body weight – adult (kg)
AT = Averaging time (days)

The exposure assumptions used to estimate exposure from fish consumption are presented in Table 3-29.

3.5.5 Calculation of Intake due to Infant Consumption of Human Milk

Exposure to breastfeeding infants due to consumption of human milk was evaluated using a methodology developed by ODEQ, OHA, and EPA Region 10, ~~and~~ adapted from EPA's Methodology for Assessing Health Risks Associated with Multiple Pathways of Exposure to Combustor Emissions (EPA 1998a) and the Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities (EPA 2005a), and is described in detail in Appendix D of the DEQ Human Health Risk Assessment Guidance (DEQ 2010)~~–~~. The evaluation for this pathway focuses on PCBs, dioxins/furans, DDx, and PDBEs because of the propensity of these chemicals to bioaccumulate~~—~~. Because the concentration of lipophilic chemicals in human milk is most directly correlated with the ~~long-term~~ steady-state body burden-, which itself is directly related to the long-te~~rm RM~~rm- intake of the chemical, the daily maternal absorbed intake is calculated from the average daily dose to the mother (as calculated in the preceding sections) using the following equation:

$$DAI_{maternal} = ADD_{maternal} \times AE$$

where:

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$DAI_{maternal}$ = daily absorbed intake of the mother (mg/kg-day)
$ADD_{maternal}$ = age-adjusted soil/sediment ingestion factor (mg/kg-day)
AE = absorption efficiency of the chemical

The steady-state chemical concentration in milk fat is then calculated as:

$$C_{milkfat} = \frac{DAI_{maternal} \times h \times f_f}{ln(2) \times f_{fm}}$$

where:

$C_{milkfat}$ = chemical concentration in milk fat (mg/kg-lipid)
$DAI_{maternal}$ = daily absorbed intake of the mother (mg/kg-day)
h = half-life of chemical (days)
f_f = fraction of absorbed chemical stored in fat
f_{fm} = fraction of mother's weight that is fat

Intake for infants via breastfeeding is then calculated as:

$$Intake = \frac{C_{milkfat} \times f_{mbm} \times CR_{milk} \times ED_{inf}}{BW_{inf} \times AT}$$

where:

f_{mbm} = fraction of fat in breast milk
CR_{milk} = ~~consunmption~~consumption rate of breast milk (kg/day)
ED_{inf} = exposure duration of breastfeeding infant (days)
BW_{inf} = average infant body weight (kg)
AT = averaging time (days)

3.5.6 Ca~~C~~alculation of Intake for Mutagenic COPCs

~~**Calculation of Intake for Mutagenic COPCs**~~

Early--in-life susceptibility to carcinogens has long been recognized by the scientific community as a public health concern~~–~~. In its revised Cancer Assessment Guidelines, EPA concluded that existing risk assessment approaches did not adequately address the possibility that exposures to a chemical in early life may can result in higher lifetime cancer risks than a comparable duration adult exposure (EPA 2005b)~~–~~. In order to address this increased risk, the agency recommends use of a potency adjustment to account for early-in-life exposures~~–~~. When no chemical-specific data are available to assess directly cancer susceptibility from early-life exposure, the following default Age Dependent Adjustment Factors (ADAFs) are recommended to be used when evaluating a carcinogen known to cause cancer through a mutagenic mode of action.

- 10-fold adjustment for exposures during the first 2 years of life;
- 3-fold adjustment for exposures from ages 2 to <16 years of age; and
- No adjustment for exposures after turning 16 years of age.

Of the COPCs evaluated in this HHRA, EPA considers that there is sufficient weight-of-evidence to conclude the carcinogenic PAHs cause cancer through a mutagenic mode of action. ~~For this HHRA, consideration of early-life stage exposure was limited to residential exposures and recreational beach users.~~

3.5.7 Incidental Ingestion of Sediment

~~**Incidental Ingestion of Sediment**~~

The following equation was used to calculate the intake in mg/kg-day for mutagenic COPCs associated with incidental ingestion of soil or sediment:

$$CDI / LADI = \frac{C_s \times \left(\begin{array}{c} \frac{(ED_{0\text{-}2} \times IRS_c) \times 10}{BW_c} + \frac{(ED_{2\text{-}6} \times IRS_c) \times 3}{BW_c} + \\ \frac{(ED_{6\text{-}16} \times IRS_a) \times 3}{BW_a} + \frac{(ED_{16\text{-}30} \times IRS_a) \times 1}{BW_a} \end{array} \right) \times EF}{AT}$$

where:

C_s = chemical concentration in soil or sediment (mg/kg)
IRS_a = adult soil/sediment ingestion rate (mg/day)
IRS_c = child soil/sediment ingestion rate (mg/day)
EF = exposure frequency (days/year)
$ED_{0\text{-}2}$ = exposure duration ages 0-2 (years)
$ED_{2\text{-}6}$ = exposure duration ages 2-6 (years)
$ED_{6\text{-}16}$ = exposure duration ages 6-16 (years)
$ED_{16\text{-}30}$ = exposure duration ages 16-30 (years)
BW_a = adult body weight (kg)
BW_c = child body weight (kg)
AT = averaging time (days)

3.5.8 Dermal Contact with Sediment

~~**Dermal Contact with Sediment**~~

The following equation was used to calculate the intake from dermal contact with contaminants in soil or sediment:

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$$CDI / LADI = \frac{C_S \times \left(\begin{array}{l} \dfrac{ED_{0\text{-}2} \times AF_c \times SA_c \times 10}{BW_c} + \dfrac{ED_{2\text{-}6} \times AF_c \times SA_c \times 3}{BW_c} + \\ \dfrac{ED_{6\text{-}16} \times AF_a \times SA_a \times 3}{BW_a} + \dfrac{(ED_{16\text{-}30} \times AF_a \times SA_a \times 1}{BW_a} \end{array} \right) \times ABS \times EF \times 10^{-6}\ kg/mg}{AT}$$

where:

C_S = chemical concentration in soil or sediment (mg/kg)
ABS = absorption efficiency
SA_a = adult exposed skin surface area (square centimeters [cm^2])
SA_c = child exposed skin surface area (cm^2)
AF_a = adult soil-to-skin adherence factor (mg/cm^2)
AF_c = child soil-to-skin adherence factor (mg/cm^2)
EF= = exposure frequency (days/year)
$ED_{0\text{-}2}$ = exposure duration ages 0-2 (years)
$ED_{2\text{-}6}$ = exposure duration ages 2-6 (years)
$ED_{6\text{-}16}$ = exposure duration ages 6-16 (years)
$ED_{16\text{-}30}$ = exposure duration ages 16-30 (years)
BW_a = adult body weight (kg)
BW_c = child body weight (kg)
AT = averaging time (days)

3.5.9 Ingestion of Surface Water

~~**Ingestion of Surface Water**~~

The following equation was used to calculate intake of chemicals associated with ingestion of surface water:

$$CDI / LADI = \frac{C_w \times \left(\begin{array}{l} \dfrac{(ED_{0\text{-}2} \times IRW_c) \times 10}{BW_c} + \dfrac{(ED_{2\text{-}6} \times IRW_c) \times 3}{BW_c} + \\ \dfrac{(ED_{6\text{-}16} \times IRW_a) \times 3}{BW_a} + \dfrac{(ED_{16\text{-}30} \times IRW_a) \times 1}{BW_a} \end{array} \right) \times EF}{AT}$$

where:

$C_{\cancel{W}w}$ = chemical concentration in water (mg/L)
IFW_{adj} = age-adjusted water ingestion factor [(L-year)/(kg-day)]
IRW_a = adult groundwater ingestion rate (L/day)
IRW_c = child groundwater ingestion rate (L/day)
EF = exposure frequency (days/year)

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ED_{0-2} = exposure duration ages 0-2 (years)
ED_{2-6} = exposure duration ages 2-6 (years)
ED_{6-16} = exposure duration ages 6-16 (years)
ED_{16-30} = exposure duration ages 16-30 (years)
BW_a = adult body weight (kg)
BW_c = child body weight (kg)
AT = averaging time (days)

~~Intakes were quantified using standard exposure equations (EPA 1989). These equations take the general form:~~

$$\cancel{\text{CDI or LADI}} = \frac{EPC \times IR \times EF \times ED}{BW \times AT}$$

~~Where:~~

- ~~CDI = Chronic daily intake~~
- ~~LADI = Lifetime average daily intake~~
- ~~EPC = Exposure point concentration~~
- ~~IR = Intake rate~~
- ~~EF = Exposure frequency~~
- ~~ED = Exposure duration~~
- ~~BW = Body weight~~
- ~~AT = Averaging time.~~

The ~~detailed intake equations, as well as the specific~~ exposure parameters ~~and associated units, are dependent on the exposure scenario evaluated; please see~~are presented in Tables 3-26 to 3-30~~ for additional details. ~~. ~~For exposure areas outside of the Study Area, the same intake equations and exposure parameters were used as used for exposure areas within the Study Area.~~

~~5.3.1~~3.5.10 Population-Specific Exposure Assumptions

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Assumptions about each receptor population evaluated in this BHHRA were used to select exposure parameters used to calculate the pathway-specific chemical intakes~~. ~~. S~~Currently, s~~ite-specific values are not available for all populations and pathways~~. ~~. Therefore, default values representative of the general U.S. population (EPA 1991b) ~~, were used where site-specific values are not available. Where default values are not available, exposure~~or values ~~were selected using~~representing best professional judgment based on ~~knowledge of~~known human uses of the Study Area~~, or requirements from EPA~~ were used~~, were used. ~~. The majority of the

~~E~~exposure parameters ~~that were~~ used in this BHHRA ~~to calculate the CDIs and LADIs for most receptors~~ were previously ~~included~~ described in the *Exposure Point Concentration Calculation Approach and Summary of Exposure Factors* (Kennedy/Jenks Consultants 2006), which was approved by EPA~~. ~~. ~~For divers, the~~ Eexposure parameters for divers were provided by EPA ~~in a directive dated September 15, 2008. For To evaluate hypothetical future domestic water use, EPA default exposure parameters for residential drinking water were used as required by EPA~~ in its comments on the ~~Round~~ Round 2 Report~~. ~~. The exposure parameters are discussed below and presented in ~~Tables~~ Tables 3~~-~~-26 to 3~~-~~-30~~. ~~. These values represent potential exposures for application at appropriate areas and/or areas agreed upon with EPA and its partners within the Study Area~~. ~~. ~~Except where specifically noted, the exposure assumptions used in the BHHRA were applied uniformly to all of~~used throughout ~~the Study Area., and may or may not be applicable at specific locations within the Study Area depending on factors not specifically addressed in the BHHRA (e.g., accessibility, habitat). AThe actual exposures for specific individuals at a given specific locations may be less than that assumed for the population and Study Area as a whole due to location-specific conditions. . Specific instances where harbor-wide values may not always be applicable are discussed in the following sections.~~

~~5.3.1.1~~3.5.10.1 Dockside Workers

~~For the dockside worker, exposure to beach sediment is the only exposure pathway determined to be potentially complete and evaluated in this BHHRA. Industrial land use was assumed only for portions of the Study Area that are zoned for industrial use and with river-front areas that include natural river beach or bank areas. Activities at Portland Harbor industrial sites do not occur frequently in these areas, which are the only areas where direct exposure to beach sediment might occur. It is unlikely that workers are in direct contact with beach sediment through typical industrial activities on a daily basis.~~ Exposure frequency for dockside workers was assumed to be 200 days/year for the RME evaluation, and 50 days/year the CT evaluation~~. ~~. The value of 200 days/year is slightly less than the EPA default exposure frequency of 225 days/year for outdoor workers, and represents the average number of days worked per year according to the U.S. Census Bureau's *1990 Earnings by Occupation and Education Survey*~~. ~~. An exposure duration of 25 years was used, representing an EPA default value for the RME estimate of job tenure~~. ~~. This value is consistent with data from the U.S. Bureau of Labor Statistics showing that the 95th percentile job tenure for men in the manufacturing sector is 25 years~~. ~~. The CT estimate assumed duration of 9 years, representing approximately the 50th percentile of residence time estimates from the U.S. Census Bureau data (EPA, 1997)~~. ~~.

A sediment ingestion rate of 200 mg/day was used for the RME evaluation, based on EPA Region 10 supplemental guidance on soil ingestion rates (EPA, 2000a), and is representative of approximately the midpoint between the recommended values of 100- mg/day for outdoor workers and 330- mg/day for construction workers~~. ~~. An ingestion rate of 50 mg/day was used to estimate CT exposure~~. ~~.

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Dermal exposure was assessed assuming that the face, forearms and hands are exposed, representing an exposed skin surface area of 3,300 cm^2, which is representative of the median value (50th percentile) for adults~~.~~. A body weight of 70 kg, representing the 50th percentile of mean body weights of men and women combined (EPA, 1997a) was used for all adult receptors~~.~~. RME and CT exposure values for dockside workers are presented in Table 3-26.~~ summarizes RME and CT exposure values for the dockside worker and the reference or rationale for each value~~

~~Because it is unlikely that significant beach sediment exposure would occur for a dockside worker on a daily basis, exposure assumptions for the dockside worker were developed using EPA default exposure values for an industrial worker for most parameters except for exposure frequency. For exposure frequency, it was assumed that a worker would contact sediment one day per week while working at the industrial site, rather than the EPA default value or 5 days per week. Therefore, the default exposure frequency of 250 days per year, which represents 5 days per week for 50 weeks, was changed to 50 days per year (i.e., 1 day per week for 50 weeks) for RME. Table 3-26 summarizes RME and CT exposure values for the dockside worker and the reference or rationale for each value.~~

~~5.3.1.2~~3.5.10.2 In-Water Workers

~~For the in-water worker, E~~Exposure to in-water surface sediment ~~by in-water workers is the only exposure pathway determined to be potentially complete and evaluated as potentially complete in this BHHRA. In-water workers could contact in-water sediment while performing specific activities; such as replacement of fender piles or maintenance dredging. Exposure factors for in-water workers for in-water sediment were developed for Terminal 4 based on in-depth interviews with several workers at Terminal 4 who either conduct or oversee activities that could result in contact with in-water sediment. .~~According to the Army Corps of Engineers (Siipola 2004), the Port of Portland conducts the most frequent dredging within the Study Area, ~~so~~ thus the exposure factors for workers at Terminal 4 are considered protective of in-water workers for potential in-water sediment exposures throughout the Study Area~~ for potential in-water sediment exposures. ~~. Exposure factors for in-water workers were developed based on in-depth interviews with several workers at Terminal 4 who either conduct or oversee activities that could result in contact with in-water sediment. For the RME ~~scenario~~evaluation, ~~in-water workers are assumed to contact~~ in-water sediment exposures were assumed to occur for 10 ~~years during~~ of 25 years of employment at a given facility, with an exposure frequency of 10 days of sediment contact per year~~.~~. For the CT ~~scenario~~evaluation, ~~in-water workers are assumed to~~ contact with in-water sediment is assumed ~~for~~ for 4 ~~years during~~of 9 years ~~of~~ employment at a given facility, with an exposure frequency of 10 days of sediment contact per year~~.~~. I~~The in-water worker exposure factor i~~ntake rates for in-water sediment are the same as those used for the dockside worker ~~for beach sediment~~, which ~~in turn~~ are the ~~same as~~ default ~~exposure factors~~ingestion rate ~~for~~ of soil for an

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industrial worker~~.~~. RME and CT exposure values for the in-water worker are presented in Table 3~~-~~-27 ~~summarizes RME and CT exposure values for the in-water worker and the reference or rationale for each value~~.

~~#### 5.3.1.3 Transients~~

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~~Transients may be exposed to beach sediment, surface water, and groundwater at seeps while utilizing river beaches. Such exposures are Transient land use is assumed to occur only for portionsat locations of within the Study Area with riverfront access which and that are not also active industrial sites. Transients may be exposed to beach sediment, surface water, and groundwater seeps while utilizing river beaches within transient use areas. As EPA does not have recommended default exposure parameters for transient scenarios, so the exposure frequency and duration for transients are based on best professional judgment. BHowever, by definition, transient exposures are assumed to occur over a short duration of time. Little information is available regarding how long individuals may remain at specific locations or within the Study Area itself. Based on professional judgment, an exposure duration of 2 years was assumed for the RME and 1 year for CT evaluations, exposure frequency was assumed to be daily (365 days/year). Incidental ingestion of sediment was evaluated at the same rates used for the dockside workers (200 mg/day). Dermal exposure was assessed assuming that the face, forearms and hands, and lower legs are exposed, representing an exposed skin surface area of 5,700 cm^2, which represents the median value for adults. A At However, at the request of EPA, it was assumed that transients might would remain at a single beach for up to two years for the RME scenarioevaluation. For intake rates for transients, EPA required that , and a the soil ingestion rate of 200 mg/day and soil adherence factor of 0.3 mg/cm^2 used bewas used for evaluating direct contact exposures tofor beach sediment be increased above those EPA default values recommended for residential soil exposures, based on the expectation that transients living on a beach sediment would have greater contact with beach sediment than a residential adult might have with soil and dust . and that residential tap water ingestion rates be used for surface water.. A higher soil ingestion rate (200 mg/day instead of 100 mg/day) and soil adherence factor (0.3 mg/cm^2 instead of 0.07 mg/cm^2) were used as it is expected that transients living on a beach would have more contact with beach sediment than a residential adult might have with residential soil and dust. a greater moisture content than dry soil. Transients may also have limited access to washing facilities and could therefore more frequently transfer sediments from hand to mouth while eating, smoking, etc. An ingestion rate of 2 L/day was used for consumption of surface water, which represents the default value for domestic water use. Tables 3-26 and 3-28 summarize RME and CT exposure values for the transient scenario for beach sediment and surface water, (surface water and groundwater seeps respectively), and the reference or and rationale for each value.~~

3.5.10.3 Divers

~~. The water ingestion rates for both diver exposure scenarios were the same as those used for the recreational beach swimmers. Tables 3-27 and 3-28 summarize exposure assumptions for the wet suit and dry suit divers for in-water sediment and surface water, respectively, and the reference or rationale for each value.~~

Two different scenarios were evaluated, based on whether the divers wear wet or dry suits~~.~~. Divers wearing wet suits are assumed to be working as commercial divers without a full face mask, and wearing either wet gloves or no gloves~~.~~. An exposure frequency of 5 days/year for the RME evaluation and 2 days/year for the CT evaluation are based on best professional judgment and discussions between EPA, LWG, and commercial divers, as well as the experience of EPA divers who work at the Portland Harbor Superfund site~~.~~. Exposure durations of 25 years and 9 years were used for the RME and CT estimates, respectively, based on the labor statistics for job tenure described in Section 3.5.~~10~~9.1.

Sediment ingestion rates were assumed to be 50 percent of the ingestion rate for dockside workers, corresponding to values of 50 mg/day and 25 mg/day, respectively for the RME and CT evaluations~~.~~. ~~Rates for incidental The water ingestion of surface water rates for both diver exposure scenarios were the same as those used for the recreational beach swimmers.r.~~

Dermal exposure to sediment was evaluated assuming the entire skin surface area was exposed~~.~~. ~~Event duration for exposure to sediment and surface water for both diver scenarios was 4 hours per diver for the RME and 2 hours per diver for the CT exposure~~ A value of 18,150 cm^2, representing the median skin surface area for men and women was used for both the RME and CT evaluations~~.~~. Divers wearing a dry suit (with a neck dam) would likely have only their head, neck, and hands exposure, and a RME value of 2,510 cm^2 was used~~.~~. S~~The~~ sediment dermal adherence factors for ~~both diver exposure scenarios were the same as those for the in-water fishers~~of 0.3 mg/cm^2-event and 0.07- mg/cm^2- event was used for the was used for the RME estimate and CT estimate, respectively~~.~~. A CT evaluation was not done for divers wearing dry suits.

Incidental ingestion of surface water for both diver scenarios was assumed to be 50 mL/hour for both the RME and CT evaluations (EPA 1989)~~, based on the recommended value from EPA's Superfund Exposure Assessment Manual.~~. More recent data regarding estimates of the amount of water ingested by commercial divers~~.~~ ~~I~~indicates that ~~O~~on average, occupational divers ingested 6 mL/dive in freshwater and 10 mL/dive in marine water, with the maximum estimated ingestion ranging between 25 and 100/mL/dive (EPA 2011)~~.~~. ~~e~~Exposure via ingestion and dermal contact was assumed to occur for 4 hours/event for the RME estimate and 2 hours/event for the CT estimate~~.~~.

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Tables 3--27 and 3--28 summarize exposure assumptions for the wet suit and dry suit divers for in-water sediment and surface water, respectively.~~, and the reference or rationale for each value.~~

3.5.10.4 Transients

Little information is available regarding how long individuals may remain at specific locations or within the Study Area itself~~.~~. Based on professional judgment, an exposure duration of 2 years was assumed for the RME and 1 year for CT evaluations, exposure frequency was assumed to be daily (365 days/year)~~.~~. Incidental ingestion of sediment was evaluated at the same rates used for the dockside workers (200 mg/day)~~.~~. Dermal exposure was assessed assuming that the face, forearms and hands, and lower legs are exposed, representing an exposed skin surface area of 5,700 cm^2, which represents the median value for adults~~.~~. A soil adherence factor of 0.3 mg/cm^2 was used based on the expectation that beach sediment would have a greater moisture content than dry soil~~.~~. An ingestion rate of 2 L/day was used for consumption of surface water, which represents the default value for domestic water use~~.~~. Tables 3--26 and 3--28 summarize RME and CT exposure values for the transient scenario for beach sediment and surface water, and the reference and rationale for each value.

~~5.3.1.4~~3.5.10.5 Recreational Beach User

~~Recreational use of beaches can result in direct contact with beach sediment within river beach areas and with surface water while swimming or during other water-related activities. Recreational beach use is assumed to occur only for portions of the Study Area where recreational exposures are reasonably likely to occur. Recreational beach users may have direct contact with beach sediment within river beach areas and with surface water while swimming or during other water activities. In the absence of EPA does not have recommendeddefault exposure parameters for recreational beach use scenarios, so potential the exposures frequency and duration for recreational beach users are based on best professional judgment as follows. Beach use was: beach use was assumed to be occur more most frequently (5 days per week) in the summer, with less frequent use in the spring/fall (1 day per week), and with only even lessintermittent use in the winter (1 day per month). Incidental ingestion of beach sediment was assumed to occur at the same rate as for soil in a residential setting (100 mg/day for adults, 200 mg/day for children), a soil-skin adherence of 3.3 mg/cm²-day was used for children to account for the greater moisture content of beach sediment versus typical soil in a residential yard. The temperature of river waterWater temperatures in the Lower Willamette River would typically limit swimming activities during much of the year. Therefore, exposure to surface water was only evaluated forto the summer months, thus s. Swhen swimming might was assuming to~~

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~~occur at a rate of (26 days per weekyear). For beach sediment intake, the recommended default values for residential soil were generally used but the adherence factor for children was more than 10 times greater than the value for residential soil. For surface water intake, the recommended default values for swimming scenarios were used. Incidental ingestion of river water while swimming was assumed to occur at a rate of 50 mL/hour while swimming. The recreational beach user includes both adults and children. Tables 3-26 and 3-28 summarize RME and CT exposure values for beach sediment and surface water, respectively, for adult and child recreational beach users. A reference or rationale is included for each value.~~In the absence of specific information regarding the frequency of recreational activities in Portland Harbor, potential exposures are based on best professional judgment, assuming that beach use is most frequent in the summer, with less frequent use in the spring/fall, and only intermittent use in the winter~~—~~. An exposure frequency of 94 days/year (5 days/week during summer, 1 day/week during spring/fall, and 1 day/month during winter) was used for the RME estimate and 38 days/year (2 days/week during summer, 2 days/month during spring/fall) was used for the CT estimate~~—~~. Exposure duration for recreational activities is based on the assumption that individuals are largely permanent residents of the Portland area~~—~~. Accordingly, an exposure duration of 30 years, which represents approximately the 95th percentile of the length of continuous residence in a single location in the U.S. population (EPA~~,~~ 1997) was used for the RME estimate~~—~~. More recent studies described in the 2011 edition of EPA's Exposure Factors Handbook show the 95th percentile value is closer to 33 years, data from the U.S. Census Bureau indicate that 32 years represents the best estimate of residence time at the 90th percentile~~—~~. However, the value of 30 years is consistent with other Superfund risk assessments nationwide, and represents a reasonably conservative estimate of total residence time in the area~~—~~. An exposure duration of 9 years was used for the CT estimate~~—~~.

Sediment ~~I~~ingestion rates of 100 mg/day for adults and 200 mg/day for children were used, approximating the 95th percentile soil ingestion rates~~—~~. CT estimates assumed sediment ingestion rates of 100 mg/day for children and 50 mg/day for adults~~—~~. Dermal exposures were evaluated assuming that the face, forearms and hands, and lower legs are exposed~~—~~. Median values of 5,700 cm^2 and 2,800 cm^2 were used for adults and children, respectively~~—~~. A soil-skin adherence of 3.3 mg/cm^2-day was used for children to account for the greater moisture content of beach sediment~~—~~.

Water temperatures in the Lower Willamette River would typically limit swimming to the summer months, thus swimming was assum~~ing~~ed to occur at a rate of 26 days per year~~—~~. As discussed in Section 3.5.10.~~5~~3, ~~I~~incidental ingestion of river water ~~while swimming~~ was assumed to occur at a rate of 50 mL/hour while swimming~~—~~. Based on current recommendations, 50 mL/hr represents mean value, assuming 21mL/hr for adults and 49 mL/hr for children, upper-percentile recommended values are 71 mL/hr for adults and 121 mL/hr for children(EPA 2011)~~—~~. Tables 3-26 and 3-28 summarize RME and CT exposure values for beach sediment and surface water, respectively, for adult and child recreational beach users~~—~~.

3.5.10.6 Recreational/Subsistence Fishers

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~~A year-round recreational fishery exists within the Study Area. Current information indicates that spring Chinook salmon, steelhead, Coho salmon, shad, crappie, bass, and white sturgeon are the fish species preferred by local recreational fishers (DEQ 2000b, Hartman 2002, and Steele 2002). In addition to recreational fishing, an investigation by the Oregonian newspaper and limited surveys conducted on other portions of the Willamette River indicate that immigrants from Eastern Europe and Asia, African-Americans, and Hispanics are most likely to be catching and eating fish from the lower Willamette either as a supplemental or primary dietary source (ATSDR 2002). These surveys also indicate that the most commonly consumed species are carp, bullhead catfish, and smallmouth bass, although other species may also be consumed. In conversations that were conducted as part of a project by the Linnton Community Center (Wagner 2004) about consumption of fish or shellfish from the Willamette River, transients reported consuming a large variety of fish, and several said they ate whatever they could catch themselves or obtain from other fishers.~~

~~Individuals who fish from the water's edge within natural river beach areas may be exposed to beach sediment, and fishing could occur from any beach area where access is not restricted. Fishing from boats or piers may result in exposure to in-water sediment due to handling anchors, hooks, or crayfish pots. As discussed in Section 3.2.1.6,~~ Because there is limited information regarding the frequency of fishing activities within the Study Area, a range of possible exposures was evaluated for people who engage in recreational or subsistence fishing activities by considering both a high-~~frequency~~ and a low-frequency rate of fishing~~.~~. RME estimates for high-frequency (subsistence) fishers assumed a fishing frequency of 156 days/year, approximating -a rate of 3 days/week~~.~~. Low-frequency (recreational) fishers were assumed to fish 104 days/year, approximating a rate of 2 days/week~~.~~. CT estimates assumed a frequency of 52 days/year and 26 days/year for high- and low-frequency fishers, respectively, and are representative of assumed fishing frequencies of 1 day/week and 2 days/month~~.~~. People engaged in recreational or subsistence fishing were also assumed to be residents of the greater Portland area, therefore exposure durations of 30 years and 9 years, ~~s~~ were used for the RME and CT evaluations, respectively, based on the population statistics for residency discussed in Section 3.5.~~10~~9.5~~.~~.

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~~Exposure to in-water sediments was evaluated for both high- and a low-frequency of fishing in order to assess a range of potential activity patterns. Although the true extent of direct contact with in-water sediment is not knownI,~~ incidental ingestion of beach sediment was evaluated assuming 100 mg/day for the RME estimate and 50 mg/day for the CT estimate, representative of soil ingestion rates in a typical residential setting~~.~~. ~~r~~Rates of 50 mg/day for the RME estimate and 25 mg/day for the CT estimate were used for incidental ingestion of in-water sediment, representing 50 percent of the rates ~~o~~fused ~~for incidental soil ingestion ratein a typical residential setting~~for beach sediment~~.~~. An exposed surface area of 5,700 cm^2, representing the

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face, hands, forearms and lower legs was used to assess dermal exposure to beach sediments, exposures to in-water ~~Direct contact of~~ sediment ~~with the~~was assumed to be limited to the hands and forearms, corresponding to a surface area of 1,980 cm^2~~.—~~. ~~was assumed to be the most likely route of dermal exposure, and dermals~~Sediment~~oil~~ adherence ~~if~~to skin ~~is~~was evaluated using a weighted adherence factor based on exposure to the hands, forearms, and lower legs (EPA 2004).– ~~in-water sediment was assumed to be similar to that for beach sediments corresponding to .~~ A factor of 25 percent was used to ~~represent the percent of~~account for the time spent fishing in a single area within the Study Area~~.—~~. E~~The e~~xposure assumptions for beach and in-water sediment contact for recreational/subsistence fishers are presented in Tables 3-2~~7~~6 and 3-27

~~Current~~Information currently available ~~information~~ indicates that spring Chinook salmon, steelhead, Coho salmon, shad, crappie, bass, and white sturgeon are the fish species preferred by local recreational fishers (DEQ 2000b, Hartman 2002, and Steele 2002)~~.—~~. In addition to recreational fishing, an investigation by the Oregonian newspaper and limited surveys conducted on other portions of the Willamette River indicate that immigrants from Eastern Europe and Asia, African-Americans, and Hispanics are most likely to be catching and eating fish from the lower Willamette either as a supplemental or primary dietary source (ATSDR 2002)~~.—~~. These surveys also indicate that the most commonly consumed species are carp, bullhead, catfish, and smallmouth bass, although other species may also be consumed~~.—~~. In conversations that were conducted as part of a project by the Linnton Community Center (Wagner 2004) about consumption of fish or shellfish from the Willamette River, transients reported consuming a large variety of fish, and several said they ate whatever they could catch themselves or obtain from other fishers~~.—~~.

No studies were located that document specific consumption rates of recreational o~~f~~r subsistence anglers in Portland Harbor prior to its listing as a Superfund site.~~, and any survey conducted since the site has was listed as a Superfund site in 2000 and~~ Surveys conducted subsequent to the listing would not be representative of historical, baseline consumption patterns due to ~~subsequent~~subsequent fish advisories and efforts to limit consumption of fish caught from the harbor~~-would not be representative of historical, baseline consumption patterns~~. Therefore, f~~Specific information is not available regarding consumption rates for locally-caught fish within the Study Area.~~ Fish c~~In order to assess a range of exposures,~~ consumption rates from published studies were used to describe the range of reasonably expected exposures relevant to the different populations known to occur in the Portland Harbor area. ~~Specific areas evaluated for potential exposure to sediments for individuals engaged in recreational or subsistence fishing include all areas designated as transient and recreational use areas.~~

~~Non-tribal fish consumption was evaluated for both adults and children while sediment exposure was evaluated for adults only, with the assumption that fishing is done primarily by adults but both adults and children may consume the fish that are~~

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~~caught.As discussed in Section 3.2.1.6, a range of possible exposures was evaluated for people who engage in recreational or subsistence fishing activities by considering both a high-frequency and a low-frequency rate of fishing. RME estimates for high-frequency fishers assumed fishing 156 days/year, approximating a rate of 3 days/week. Low-frequency fishers were assumed to fish 104 days/year, approximating a rate of 2 days/week. CT estimates assumed a frequency 52 days/year and 26 days/year for high- and low-frequency fishers, respectively, and are representative of assumed fishing frequencies of 1 day/week and 2 days/month. Dermal exposure was evaluated assuming the same exposed skin surface area for adults of 5,700 cm^2 used for recreational exposure. People engaged in recreational or subsistence fishing were also assumed to be residents of the Portland area, therefore exposure durations of 30 years and 9 years were used for the RME and CT evaluation, respectively. At the request of EPA, the exposure frequencies and durations for beach sediment for each fisher scenario were assumed to represent the fishing activity at the Study Area regardless of whether that fishing occurs from a beach or a boat. A factor of 25 percent was used to represent the percent of time spent fishing in a single area within the Study Area.~~

~~Based on the exposure scenarios for in-water sediment (i.e., contact with sediment on anchors, hooks, or crayfish pots), the extent of contact with in-water sediment is expected to be less than what would occur with residential soil. Ingestion rates for soil are based on exposure to soil during yard work and to indoor dust (EPA 1997a). These ingestion rates are not applicable to the in-water sediment exposure scenarios; however, incidental ingestion rates are not available for sediment. It is assumed that the incidental ingestion rate for in-water sediment is 50 percent of the ingestion rate for residential incidental soil scenarios. For dermal contact, hands and forearms are the only body parts that could be exposed to in-water sediment on a regular basis (i.e., on a year-round basis). It is assumed that the entire surface area of both hands and forearms would be exposed to in-water sediment. The adherence and absorption factors are assumed to be the same as those for beach sediment. Exposure assumptions for in-water sediment contact for fishers are presented in Table 3-27~~

~~T The fish consumption scenario included t~~hree different ~~fish fish ingestionconsumption~~ rates were evaluated~~ in the human health risk assessment~~: 17.5 grams per day (approximately 2 eight ounce meals per month), 73 g/ day (10 eight ounce meals per month), and 142 g/day per day (19 eight ounce meals per month)~~. –~~. The te~~rm RM~~rm- “recreational fishers” is intended to encompass a ~~broader spectrum~~range of the population~~, including those who may infrequently catch and consume fish, as well as~~ while focusing on those who may ~~do so~~fish on a more-or-less regular basis, and “subsistence fishers” to represent populations with high fish consumption rates, recognizing that fish are not an exclusive source of protein in their diet. Accordingly, 17.5 g/day is considered representative of a CT value for recreational fishers, and 73 g/day was selected as the RME value representing the higher-end consumption practices of recreational fishers. The consumption rate of 142 g/day represents a RME value for high fish consuming, or subsistence, fishers.

No CT value was selected because the evaluations based on 17.5 g/day and 73 g/day info~~rm RM~~rm- the risks associated with lower consumption rates. Consumption rates for children aged 6 years and younger were calculated by assuming that their rate of fish consumption is approximately 42 percent of an adult, based on the ratio of child-to-adult consumption rates presented in the CRITFC Fish Consumption Survey (CRITFC 1994). The corresponding rates that were used for children are 7 g/day, 31 g/day, and 60 g/day.

The rates of 17.5- g/day and 142 g/day represent the 90th and 99th percentiles, respectively, of per capita consumption of uncooked freshwater/estuarine finfish and shellfish ~~of~~by individuals (consumers and non-consumers) 18 or older, as reported in the Continuing Survey of Food Intakes by Individuals (CSFII) and described in EPA's Estimated Per Capita Fish Consumption in the United States -(EPA 2002b)~~.~~—. While the values are presented in terms of "uncooked weight," it should not be construed to imply that the fish are consumed raw, as the consumption rates represent adjusted values to account for the amount of fish needed to prepare specific meals. No adjustments were made to contaminant concentrations in raw fish tissue because of the uncertainties associated with accounting for specific preparation and cooking practices.

The CSFII surveys recorded food consumption for two non-consecutive days~~.~~—. ~~For the purpose of the report,~~ "~~c~~Consumers only" were defined as individuals who ate fish at least once during the 2—day reporting period, individuals who reported not consuming any fish during the reporting period were designated as "non-consumers."~~.~~ For comparison, the 90th and 99th percentile consumption rates for consumers-only are 200 g/day and 506 g/day, respectively (EPA 2002b)~~.~~—. Because of the~~Therefore, the limited~~short time period ~~of dietary intake collection~~ over which the survey is conducted, the results characterize the empirical distribution of average daily per capita consumption ~~does not produce usual~~rather than describe true long-te~~rm RM~~rm- ~~intake estimates. Usual intakes are defined as "the long run~~ average ~~of~~ daily intakes ~~of a dietary component by an individual~~. Although 17.5 g/day represents a 90th percentile value, it is considered an average consumption rate for sport fishers (EPA 2000d)~~.~~—. Similarly, 142 g/day is considered to be representative of average consumption estimates for subsistence fishers when compared to upper percentile values for consumers only. However, the use of values representative of both non-consumers and consumers is appropriate as it accounts for the fact that some portion of the total diet of fish consumed may come from sources other than Portland Harbor. ~~" Use of the combined "consumer" and "non-consumer" per capita consumption rates reduces bias introduced by using only the values for those individuals that actually consumed fish during the survey period. Rather, the estimates presented in this report characterize the empirical distribution of daily average per capita consumption For comparison, the 90th and 99th percentile ingestion ratesconsumption rates for consumers-only are uncooked freshwater and estuarine finfish and shellfish for consumers-only are 200 g/day and 506 g/day, respectively (EPA 2002b).~~

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The consumption rate of 73 g/day is from a creel study conducted in the Columbia Slough~~.~~, and represents the 95 percent upper confidence limit on the mean, where 75 percent of the mass of the total fish is consumed ~~The value of 73 g/day represents the 95 percent upper confidence limit on the mean consumption rate from a creel study conducted in the Columbia Slough~~ (Adolfson 1996)~~)., as well as single species and multiple species diets of resident fish species. . The term "recreational fishers" is intended to encompass a broader spectrum of the population, including those who may infrequently catch and consume fish, as well as to those who may do so on a more-or-less regular basis. . Accordingly, the 17.5 g/day consumption rate is considered arepresentative of a CT value for fish consumption for recreational fishers, and the 73 g/day rate was selected as the RME value representing the higher-end consumption practices of recreational fishers. . The consumption rate of 142 g/day represents a RME value for high fish consuming, or subsistence, fishers. . NO o CT value was evaluatedselected because the evaluations based on 17.5 g/day and 73 g/day inform the risks associated with lower consumption rates. . Study Area-specific fish consumption information is not available for the fish consumption scenarios. Therefore, to evaluate the potential range in consumption patterns that may exist, three ingestion rates were used to calculate intakes for adults and three were used for children. EPA specified the ingestion rates used in this BHHRA. For adults, the fish ingestion rates were 17.5 grams per day (g/day), 73 g/day, and 142 g/day. These rates correspond to approximately 2 meals per month, 10 meals per month, and 19 meals per month, based on an 8-ounce serving size, every month of the year, consisting exclusively of fish caught within the Study Area. It should be noted that the current fish consumption advisory, based on PCBs, for the LWR recommends that children and expectant mothers do not eat resident fish from the Portland Harbor, and that healthy adults eat no more than one 8-ounce meal per month of resident fish from the Portland Harbor (ODHS 2007). However, it is unclear to what extent this advisory is followed by people who consume fish from the Study Area.~~

~~Consumption rates for children aged 6 years and younger were calculated by assuming that their rate of fish consumption is approximately 42 percent of an adult, based on the ratio of child-to-adult consumption rates Two of these rates, 17.5 g/day and 142 g/day, represent the 90th and 99th percentile ingestion rates for diets including uncooked freshwater and estuarine finfish and shellfish by individuals (consumers and non-consumers) of age 18 and over in the United States (EPA 2002b). The 90th and 99th percentile ingestion rates for uncooked freshwater and estuarine finfish and shellfish for consumers only are 200 g/day and 506 g/day, respectively (EPA 2002b). Because these rates are from a national dietary study, they may not be representative of site-specific consumption patterns. Relative to the ingestion rate of 142 g/day, an adult consuming fish and shellfish tissue at a rate of 200 g/day would need approximately 70 percent of their total fish and shellfish diet to be fish caught within the Study Area, and an adult consuming fish and shellfish tissue at a rate of 506 g/day would need approximately 28 percent of their total fish and shellfish diet to be fish caught within the Study Area. If a different proportion of fish were caught within the Study Area versus outside of the Study Area, exposure to~~

~~chemicals within the Study Area would change accordingly. Additional uUncertainties associated with these ingestion rates are discussed in Section 6. The other ingestion rate used in this BHHRA, 73 g/day, is from a creel study conducted in the Columbia Slough and is the 95 percent upper confidence limit on the average for ingestion of fish where 75 percent of the mass of the total fish is consumed (Adolfson 1996). While this study may be more representative of consumption patterns for the Study Area, the study was limited in scope and the reported ingestion rates were estimated based on numerous assumptions. These ingestion rates were used for both the mean and 95 percent UCL/max risk calculations.~~

~~Limited information is available about fish consumption by children. The child scenario evaluated in this BHHRA is for 0 to 6-year olds. Th e national dietary study does not include consumption information for this age range. However, this age range was evaluated inpresented in the CRITFC Fish Consumption Survey (CRITFC 1994). .). In that survey, the ratio of the child 95th percentile ingestion to the adult 95th percentile ingestion rate, which is the comparison specified by EPA, was 0.42. This ratio was applied to the three adult ingestion rates to estimate the child ingestion rates. The corresponding rates that were used for children wereare 7 g/day, 31 g/day, and 60 g/day. . Exposure assumptions for recreational/subsistence fish consumption are presented in Table 3-29., and the uncertainties associated with these consumption rates are discussed in Section 6.~~

~~For the fish consumption scenarios, risks were evaluated separately for consumption of each individual target resident fish species (smallmouth bass, black crappie, brown bullhead, and common carp) assuming only one species was consumed in each scenario. For these individual species scenarios the ingestion rates for the entire diet (regardless of species) were used with concentration data on each individual resident species (for both whole body and fillet tissue). EPCs were calculated for fishing zones (common carp, black crappie and brown bullhead) and mile reach (smallmouth bass) as well as for the entire Study Area, as described in Section 3.4.5. In addition to the individual species diet, a multiple species diet was also evaluated by using the fish ingestion rates for the scenarios with the concentration data of all resident species (for whole body and fillet tissue) for the Study Area (i.e., a multiple species diet assuming that each of the 4 fish target species represents 1/4 of a person's diet). The following scenarios were evaluated for each of the above ingestion rates using both the 95 percent UCL/max and mean EPCs described in Section 3.4.5 for both whole body and fillet samples (because these scenarios were not classified as CT or RME):~~

	~~**River Mile**~~	~~**Fishing Zone**~~	~~**Entire Study Area**~~
~~Smallmouth bass~~	~~X~~		~~X~~

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~~Black crappie~~		~~X~~	~~X~~
~~Common carp~~		~~X~~	~~X~~
~~Brown bullhead~~		~~X~~	~~X~~
~~Multiple species~~			~~X~~

~~The uncertainties associated with the fish consumption scenarios are discussed in Section 6 of this BHHRA.~~

~~Because site-specific information is not available for shellfish consumption, a range of ingestion rates was evaluated in this BHHRA for adult shellfish consumers.Site-specific shellfish consumption information is not available.~~ Consumption of shellfish was evaluated ~~For shellfish,~~considering only ~~adult~~ consumption by adults~~was evaluated.~~ , and assuming that consumption of shellfish is primarily a component of a subsistence diet. Site-specific information regarding consumption of shellfish is not available, thus a range of consumption rates were evaluated. ~~. It should be noted that there is currently a fish consumption advisory for wood-treating chemicals in a portion of the Study Area recommending that crayfish not be eaten (ODHS 2007).~~ ~~Ingestion~~Consumption rates of 3.3 g/day and 18 g/day were selected as representative of CT and RME estimates ~~, were used to calculate intakes from shellfish consumption. These values representing~~These values represent the 50th ~~percentile (3.3 g/day)~~ and 95th percentile ~~(18 g/day) ingestion~~consumption rates ~~for~~of shellfish ~~consumption~~ from freshwater and estuarine systems for individuals of age 18 and older in the United States (EPA 2002b). ~~These ingestion rates were used with 95 percent UCL/max and mean EPCs for crayfish and clams described in Section 3.4.5 (because these scenarios were not classified as CT or RME). Exposure assumptions for shellfish consumption are presented in Table 3-29. The uncertainties associated with the shellfish consumption scenario are discussed in Section 6 of this BHHRA.~~

Exposure assumptions for recreational/subsistence fish consumption are presented in Table 3-29, and the uncertainties associated with these consumption rates are discussed in Section 6~~.~~.

3.5.10.7 Tribal Fishers

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~~The LWR provides a ceremonial and subsistence fishery for Native American tribes. . Four of the six Native American tribes (Yakama, Umatilla, Nez Perce, and Warm Springs) involved in the Portland Harbor RI/FS participated in a fish consumption survey that was conducted on the reservations of the participating tribes and completed in 1994 [Columbia River Inter-tribal Fish Commission (CRITFC) 1994]. . The results of the survey show that tribal members surveyed generally consume more fish than the general public. . Certain species, especially salmon and Pacific lamprey, are an important food source as well as an integral part of the tribes' cultural, economic, and spiritual heritage. .~~

Specific information regarding population mobility on ~~n~~Native American populations is less readily available than for the general U.S. population. The evaluation of exposures to ~~n~~Native Americans was based on the premise that they spend their entire lives in the area (EPA 2005c), and a typical lifetime was evaluated as 70 years. Fishing frequency was assumed to be 260 days/yr (5 days/week) for the RME estimate and 104 days/year (2 days/week) for the CT estimate~~.~~. ~~Specific information regarding population mobility on native American populations is less readily available than for the general U.S. population. . However, input during the scoping of the Portland Harbor risk assessment indicated that this population should be considered less mobile for a variety of reasons. . Hence, the evaluation of exposures to native Americans was based on the premise that they spend their entire lives in the area, and a typical lifetime was evaluated as 70 years.~~

~~ISediment ingestion rates of beach sediment for tribal fishers were evaluated at the same rate as for recreational/subsistence fishers.~~Incidental ingestion of beach sediment was evaluated assuming 100 mg/day for the RME estimate and 50 mg/day for the CT estimate~~.~~. Rates of 50 mg/day for the RME estimate and 25 mg/day for the CT estimate were used for incidental ingestion of in-water sediment, representing 50 percent of the rates used for incidental soil ingestion in a typical residential setting~~.~~. An exposed surface area of 5,700 cm^2, representing the face, hands, forearms and lower legs was used to assess dermal exposure to beach sediments, exposures to in-water sediment was assumed to be limited to the hands and forearms, corresponding to a surface area of 1,980 cm^2~~.~~. Sediment adherence to skin was evaluated using a weighted adherence factor based on exposure to the hands, forearms, and lower legs (EPA 2004)~~.~~. A factor of 25 percent was used to account for the time spent fishing in a single area within the Study Area. ~~Fishing frequency was assumed to be 260 days/yr (5 days/week) for the RME estimate and 104 days/year (2 days/week) for the CT estimate. Specific information regarding population mobility on native American populations is less readily available than for the general U.S. population. However, input during the scoping of the Portland Harbor risk assessment indicated that this population should be considered less mobile for a variety of reasons. Hence, the evaluation of exposures to native Americans was based on the premise that they spend their entire lives in the area, and a typical lifetime was evaluated as 70 years.~~

~~Tribal fishers were assumed to fish from the same beach area five days per week for the entire year (260 days/year) for an entire lifetime (70 years) for the RME. Although it is not known how much sediment contact actually occurs during fishing activities, default intake values for residential soil were used.~~ Exposure assumptions for beach– and in-water sediment contact for tribal fishers are presented in Tables- 3--26 and 3-27.

Fish consumption by tribal members was evaluated assuming a~~A~~ multi-species diet that includes both resident ~~fish as well as~~and anadromous fish (salmon~~ids~~, lamprey, and sturgeon)~~ was evaluated for tribal fish consumption.~~. An overall rate of 175 g/day (approximately 23 eight oz meals per month), representing the ~~While site-specific fish consumption information is not available for the tribal fish consumption scenario, a fish consumption survey was conducted on the reservations of four of the participating Tribes (CRITFC 1994). The~~ 95th percentile of ~~fish ingestion~~consumption rates for consumers and non-consumers ~~only from~~in the CRITFC ~~Fish Consumption~~ Survey~~, which is 175 g/day,~~ was used ~~to calculate intakes~~ for adult tribal fish consumers~~.~~. A consumption rate of 73 g/day, representing ~~On October 23, 2008, the Oregon Environmental Quality Commission approved a fish consumption rate of 175 g/day, referenced from the CRITFC (1994) survey, as the basis for ODEQ to revise state water quality standards. To date, the water quality standards have not yet been revised using the fish consumption rate of 175 g/day. This rate corresponds to approximately 23 meals per month every month of the year of fish caught exclusively within the Study Area. The CRITFC survey reported that none of the respondents fished the Willamette River for resident fish and approximately 4 percent fished the Willamette River for anadromous fish. T~~the 95th percentile ~~fish ingestion~~of consumption ~~rate of 73 g/day~~ for children from the CRITFC ~~Fish Consumption~~ Survey was used for child tribal fish consumers~~.~~. ~~Exposure assumptions for tribal fish consumption are presented in Table 3-29.~~

~~A multi-species diet was evaluated using the fish consumption data from the CRITFC Fish Consumption Survey (CRITFC 1994) with concentration data from the target resident species as well as from sturgeon, salmon and lamprey caught as a part of the ODHS sampling effort.~~ The CRITFC survey reported that none of the respondents fished the Willamette River for resident fish, and approximately 4~~-~~ percent fished ~~the Willamette River~~ for anadromous fish. ~~The~~ Overall fish consumption information from the CRITFC survey was used to determine the ingestion rate for each fish species, as shown below:

Species	**Grams per day**[a]	**Percent of diet**
Salmon	67	38.4

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Species	Grams per day[a]	Percent of diet
Lamprey	12.3	7.0
Sturgeon	8.6	4.9
Smelt	12.5	7.2
Whitefish	23.2	13.3
Trout	25.1	14.3
Walleye	9.9	5.7
Northern Pikeminnow	3.7	2.1
Sucker	7.3	4.2
Shad	5.2	3.0
Total ~~Ingestion~~Consumption Rate	175	100

(a) ~~Grams per day~~Rates are based on the weighted mean data in Table 18 of ~~the~~ CRITFC ~~Fish Consumption survey~~1994.

~~For adult tribal consumers, the ingestion~~As shown, consumption rates ~~for~~of anadromous species ~~(salmonids (67 g/day), lamprey (12.3 g/day), and sturgeon (8.6 g/day) were used in conjunction with the respective EPCs for each species to calculate intakes~~account for approximately 50 percent of total intake~~.~~. Thus, consumption of salmon, lamprey and sturgeon were equally apportioned at a combined consumption rate of 88 g/day, and the remaining portion of the diet was evaluated assuming equal portions of the four resident fish (smallmouth bass, brown bullhead, common carp, and black crappie) for which tissue data were available~~.~~. ~~For the remaining species, each of the 95 percent UCL/max and mean EPCs calculated for the entire Study Area for smallmouth bass, black crappie, common carp, and brown bullhead were used with an ingestion rate of 21.7 g/day (i.e., the ingestion rate for the sum of the species that are not anadromous salmonid, sturgeon or lamprey, 86.9 g/day, divided by 4). The combined intakes from anadromous salmonids and lamprey, from sturgeon, and from the remaining fish species in the above table were used to estimate risks from fish consumption. The intakes~~Consumption rates for children ~~tribal fish consumers~~ were calculated using the same dietary percentages as the adult tribal fish consumers~~, but with a total ingestion~~ and a total intake~~rate~~ of 73 g/day~~.~~. Exposure assumptions for tribal fish consumption are presented in Table 3-29~~.~~.

Adult salmon, adult lamprey, and sturgeon have life histories such that significant ~~exposure to~~ contaminants loading can occur outside of the Study Area, making it problematic to associate tissue concentrations with site contamination~~.~~.

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However, including consumption of anadromous fish in conjunction with resident fish provides useful information regarding risks to tribal members who may fish the Lower Willamette River. ~~a.~~

~~Exposure assumptions for tribal fish consumption are presented in Table 3-29.The uncertainties in estimating the proportion of contaminants in sturgeon, salmon and lamprey and associated risks that result from contaminants at the Study Area are discussed in Section 6.~~

~~**Domestic Water User**~~

~~Although there is no known current use of surface water within the Study Area as a domestic water supply. Because it is a designated beneficial use of the Willamette River, the use of river water as a domestic water source was assessed as a potentially complete pathway. Exposure to surface water could hypothetically occur from ingestion and dermal contact throughout the Study Area. At the direction of the EPA, volatilization of chemicals from untreated surface water to indoor air through household uses was identified as a potentially complete exposure pathway for hypothetical future domestic water use.~~

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~~**5.3.1.5 Non-Tribal Fishers**~~

~~Exposure assessments for the non~~Non-tribal fisher scenarios evaluated potential~~may be~~ exposed ~~ure~~ to COPCs through direct contact with beach and in-water sediment, and through consumption of fish and shellfish. Direct contact with beach sediment only occurs in river beach areas where fishing activities occur. Non-tribal fishers could theoretically contact in-water sediment on anchors, hooks, or crayfish pots while fishing from boats or piers at the Study Area. For fish and shellfish consumption, it is assumed that exposure could occur throughout the Study Area and is continuous year-round as fishers may catch fish at the Study Area and then freeze them for later use.~~

~~This BHHRA evaluated both a non-tribal fisher exposure scenario and a tribal fisher exposure scenario, which is discussed in Section 3.5.1.6. The non-tribal fisher scenario included two different fishing frequencies for sediment exposures, three different ingestion rates for fish consumption exposures, and two different ingestion rates for shellfish consumption exposures. Non-tribal fish consumption was evaluated for both adults and children while sediment exposure was evaluated for adults only, with the assumption that fishing is done primarily by adults but both adults and children may consume the fish that are caught.~~

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~~5.3.1.5.1 Beach Sediment Exposure~~

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~~Beach sediment exposure would only occur for fishers during bank fishing at natural river beach areas within the Study Area. EPA specified the exposure frequencies and durations for the fishers used in this BHHRA. High-frequency fishers were assumed to fish from the same beach area three days per week for the entire year (156 days/year) for 30 years for the RME. Low-frequency fishers were assumed to fish from the same beach area for two days per week for the entire year (104 days/year)for 30 years for the RME. Exposure assumptions for beach sediment contact for fishers are presented in Table 3-26.~~

~~5.3.1.5.2 In-Water Sediment Exposure~~

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~~At the request of EPA, the exposure frequencies and durations for beach sediment for each fisher scenario were assumed to represent the fishing activity at the Study Area regardless of whether that fishing occurs from a beach or a boat. A factor of 25 percent was used to represent the percent of time spent fishing in a single area within the Study Area.~~

~~Based on the exposure scenarios for in-water sediment (i.e., contact with sediment on anchors, hooks, or crayfish pots), the extent of contact with in-water sediment is expected to be less than what would occur with residential soil. Ingestion rates for soil are based on exposure to soil during yard work and to indoor dust (EPA 1997a). These ingestion rates are not applicable to the in-water sediment exposure scenarios; however, incidental ingestion rates are not available for sediment. It is assumed that the incidental ingestion rate for in-water sediment is 50% percent of the ingestion rate for residential incidental soil scenarios. For dermal contact, hands and forearms are the only body parts that could be exposed to in-water sediment on a regular basis (i.e., on a year-round basis). It is assumed that the entire surface area of both hands and forearms would be exposed to in-water sediment. The adherence and absorption factors are assumed to be the same as those for beach sediment. Exposure assumptions for in-water sediment contact for fishers are presented in Table 3-27.~~

~~5.3.1.5.3 Fish Consumption~~

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~~The fish consumption scenario included three different fish ingestion rates, as well as single species and multiple species diets of resident fish species. Study Area-specific fish consumption information is not available for the fish consumption scenarios. Therefore, to evaluate the potential range in consumption patterns that may exist, three ingestion rates were used to calculate intakes for adults and three were used for children. EPA specified the ingestion rates used in this BHHRA. For adults, the fish ingestion rates were 17.5 grams per day (g/day), 73 g/day, and 142 g/day. These rates correspond to approximately 2 meals per month, 10 meals per month, and 19 meals per month, based on an 8-ounce serving size, every month of the year, consisting exclusively of fish caught within the Study Area. It should be noted that the current fish consumption advisory, based on PCBs, for the LWR recommends that children and expectant mothers do not eat resident fish from the Portland Harbor, and that healthy adults eat no more than one 8-ounce meal per month of resident fish from the~~

~~Portland Harbor (ODHS 2007). However, it is unclear to what extent this advisory is followed by people who consume fish from the Study Area.~~

~~Two of these rates, 17.5 g/day and 142 g/day, represent the 90th and 99th percentile ingestion rates for diets including uncooked freshwater and estuarine finfish and shellfish by individuals (consumers and non-consumers) of age 18 and over in the United States (EPA 2002b). The 90^{th} and 99^{th} percentile ingestion rates for uncooked freshwater and estuarine finfish and shellfish for consumers-only are 200 g/day and 506 g/day, respectively (EPA 2002b). Because these rates are from a national dietary study, they may not be representative of site-specific consumption patterns. Relative to the ingestion rate of 142 g/day, an adult consuming fish and shellfish tissue at a rate of 200 g/day would need approximately 70 percent of their total fish and shellfish diet to be fish caught within the Study Area, and an adult consuming fish and shellfish tissue at a rate of 506 g/day would need approximately 28 percent of their total fish and shellfish diet to be fish caught within the Study Area. If a different proportion of fish were caught within the Study Area versus outside of the Study Area, exposure to chemicals within the Study Area would change accordingly. Additional uncertainties associated with these ingestion rates are discussed in Section 6. The other ingestion rate used in this BHHRA, 73 g/day, is from a creel study conducted in the Columbia Slough and is the 95 percent upper confidence limit on the average for ingestion of fish where 75 percent of the mass of the total fish is consumed (Adolfson 1996). While this study may be more representative of consumption patterns for the Study Area, the study was limited in scope and the reported ingestion rates were estimated based on numerous assumptions. These ingestion rates were used for both the mean and 95%~~ percent ~~UCL/max risk calculations.~~

~~Limited information is available about fish consumption by children. The child scenario evaluated in this BHHRA is for 0 to 6-year olds. The national dietary study does not include consumption information for this age range. However, this age range was evaluated in the CRITFC Fish Consumption Survey (CRITFC 1994). In that survey, the ratio of the child 95^{th} percentile ingestion to the adult 95^{th} percentile ingestion rate, which is the comparison specified by EPA, was 0.42. This ratio was applied to the three adult ingestion rates to estimate the child ingestion rates. The corresponding rates that were used for children were 7 g/day, 31 g/day, and 60 g/day. Exposure assumptions for fish consumption are presented in Table 3-29.~~

~~For the fish consumption scenarios, risks were evaluated separately for consumption of each individual target resident fish species (smallmouth bass, black crappie, brown bullhead, and common carp) assuming only one species was consumed in each scenario. For these individual species scenarios the ingestion rates for the entire diet (regardless of species) were used with concentration data on each individual resident species (for both whole body and fillet tissue). EPCs were calculated for fishing zones (common carp, black crappie and brown bullhead) and mile reach (smallmouth bass) as well as for the entire Study Area, as described in Section 3.4.5. In addition to~~

~~the individual species diet, a multiple species diet was also evaluated by using the fish ingestion rates for the scenarios with the concentration data of all resident species (for whole body and fillet tissue) for the Study Area (i.e., a multiple species diet assuming that each of the 4 fish target species represents 1/4 of a person's diet). The following scenarios were evaluated for each of the above ingestion rates using both the 95%~~ ~~percent~~ ~~UCL/max and mean EPCs described in Section 3.4.5 for both whole body and fillet samples (because these scenarios were not classified as CT or RME):~~

	~~River Mile~~	~~Fishing Zone~~	~~Entire Study Area~~
~~Smallmouth bass~~	~~X~~		~~X~~
~~Black crappie~~		~~X~~	~~X~~
~~Common carp~~		~~X~~	~~X~~
~~Brown bullhead~~		~~X~~	~~X~~
~~Multiple species~~			~~X~~

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~~The uncertainties associated with the fish consumption scenarios are discussed in Section 6 of this BHHRA.~~

~~5.3.1.5.4 Shellfish Consumption~~

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~~Site-specific shellfish consumption information is not available. For shellfish, only adult consumption was evaluated. It should be noted that there is currently a fish consumption advisory for wood-treating chemicals in a portion of the Study Area recommending that crayfish not be eaten (ODHS 2007). Ingestion rates of 3.3 g/day and 18 g/day were used to calculate intakes from shellfish consumption. These values represent the 50th percentile (3.3 g/day) and 95th percentile (18 g/day) ingestion rates for shellfish consumption from freshwater and estuarine systems for individuals of age 18 and older in the United States (EPA 2002b). These ingestion rates were used with 95%~~ ~~percent~~ ~~UCL/max and mean EPCs for crayfish and clams described in Section 3.4.5 (because these scenarios were not classified as CT or RME). Exposure assumptions for shellfish consumption are presented in Table 3-29. The uncertainties associated with the shellfish consumption scenario are discussed in Section 6 of this BHHRA.~~

~~5.3.1.6 Tribal Fishers~~

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~~For thousands of years, the Willamette River has been an important ceremonial and subsistence fishery (i.e., salmon, lamprey, and sturgeon) for Native American tribes of the region. Native Americans continue to rely on the Willamette River. For example, tribal members conduct a ceremonial spring Chinook harvest and continue to harvest lamprey at Willamette Falls annually.~~

~~5.3.1.6.1 Beach Sediment Exposure~~

~~Beach sediment exposure would only occur for tribal fishers during bank fishing at natural river beach areas within the Study Area. EPA provided the exposure frequencies and durations for the tribal fishers used in this BHHRA. Tribal fishers were assumed to fish from the same beach area five days per week for the entire year (260 days/year) for an entire lifetime (70 years) for the RME. Although it is not known how much sediment contact actually occurs during fishing activities, default intake values for residential soil were used. Exposure assumptions for beach sediment contact for tribal fishers are presented in Table 3-26.~~

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~~5.3.1.6.2 In-Water Sediment Exposure~~

~~At the request of EPA, the exposure frequencies and durations for beach sediment were assumed to represent the fishing frequency at the Study Area regardless of whether that fishing occurs from a beach or a boat. Therefore, a factor of 25 percent was used to represent the percent of time exposed to in-water sediment while fishing in a single area within the Study Area.~~

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~~Contact with sediment on anchors or hooks represents the most likely exposure route for contact with in-water sediments for tribal fishers. Ingestion rates for soil are based on exposure to soil during yard work and to indoor dust (EPA 1997a). These ingestion rates are not applicable to the in-water sediment exposure scenarios; however, incidental ingestion rates are not available for sediment. It is assumed that the incidental ingestion rate for in-water sediment is 50%~~ ~~percent~~ ~~of the ingestion rate for residential soil scenarios. For dermal contact, hands and forearms are the only body parts that could be exposed to in-water sediment on a regular basis. It is assumed that the entire surface area of both hands and forearms would be exposed to in-water sediment. The adherence and absorption factors are assumed to be the same as those for beach sediment. Exposure assumptions for in-water sediment contact for tribal fishers are presented in Table 3-27.~~

~~5.3.1.6.3 Tribal Fish Consumption~~

~~A multi-species diet that includes resident fish as well as salmonids, lamprey, and sturgeon was evaluated for tribal fish consumption. While site-specific fish consumption information is not available for the tribal fish consumption scenario, a fish consumption survey was conducted on the reservations of four of the participating Tribes (CRITFC 1994). The 95th percentile fish ingestion rate for consumers only from the CRITFC Fish Consumption Survey, which is 175 g/day, was used to calculate intakes for adult tribal fish consumers. On October 23, 2008, the Oregon Environmental Quality Commission approved a fish consumption rate of 175 g/day, referenced from the CRITFC (1994) survey, as the basis for ODEQ to revise state water quality standards. To date, the water quality standards have not yet been revised using the fish consumption rate of 175 g/day. This rate corresponds to approximately 23 meals per month every month of the year of fish caught exclusively within the Study Area. The CRITFC survey reported that none of the respondents fished the Willamette River for resident fish and approximately 4 percent fished the~~

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~~Willamette River for anadromous fish. The 95th percentile fish ingestion rate of 73 g/day for children from the CRITFC Fish Consumption Survey was used for child tribal fish consumers. Exposure assumptions for tribal fish consumption are presented in Table 3-29.~~

~~A multi-species diet was evaluated using the fish consumption data from the CRITFC Fish Consumption Survey (CRITFC 1994) with concentration data from the target resident species as well as from sturgeon, salmon and lamprey caught as a part of the ODHS sampling effort. The fish consumption information from the CRITFC survey was used to determine the ingestion rate for each fish species, as shown below:~~

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~~Species~~	~~Grams per day[(a)]~~	~~Percent of diet~~
~~Salmon~~	~~67~~	~~38.4~~
~~Lamprey~~	~~12.3~~	~~7.0~~
~~Sturgeon~~	~~8.6~~	~~4.9~~
~~Smelt~~	~~12.5~~	~~7.2~~
~~Whitefish~~	~~23.2~~	~~13.3~~
~~Trout~~	~~25.1~~	~~14.3~~
~~Walleye~~	~~9.9~~	~~5.7~~
~~Northern Pikeminnow~~	~~3.7~~	~~2.1~~
~~Sucker~~	~~7.3~~	~~4.2~~
~~Shad~~	~~5.2~~	~~3.0~~
~~Total Ingestion Rate~~	~~175~~	~~100~~

3.5.10.8 Domestic/Household Water User

~~(a) Grams per day are based on the weighted mean data in Table 18 of the CRITFC Fish Consumption survey.~~

~~For adult tribal consumers, the ingestion rates for anadromous salmonids (67 g/day), lamprey (12.3 g/day), and sturgeon (8.6 g/day) were used~~ in conjunction ~~with the respective 95%~~ percent ~~UCL/max and mean EPCs for those~~ each ~~species to calculate intakes. For the remaining species, each of the 95%~~ percent ~~UCL/max and mean EPCs calculated for the entire Study Area for smallmouth bass, black crappie, common carp, and brown bullhead were used with an ingestion rate of 21.7 g/day (i.e., the ingestion rate for the sum of the species that are not anadromous salmonid, sturgeon or lamprey, 86.9 g/day, divided by 4). The combined intakes from anadromous salmonids and lamprey, from sturgeon, and from the remaining fish species in the above table were used to estimate risks from fish consumption. The intakes for child tribal fish consumers were calculated using the same dietary~~

~~percentages as the adult tribal fish consumers, but with a total ingestion rate of 73 g/day.~~

~~Adult salmon, adult lamprey, and sturgeon have life histories such that significant exposure to contaminants can occur outside of the Study Area. The uncertainties in estimating the proportion of contaminants in sturgeon, salmon and lamprey and associated risks that result from contaminants at the Study Area are discussed in Section 6.~~

~~5.3.1.7 Divers~~

~~1.0 Divers could contact in-water sediment and surface water while performing specific commercial diving activities such as marine construction, underwater inspections, and routine operation and maintenance. As previously discussed in Section 3.3.2.2, exposure factors for divers were provided as a directive from EPA in a memorandum dated September 15, 2008 (EPA 2008c). The EPA developed two exposure scenarios to differentiate exposures by divers wearing wet suits from exposures by divers wearing dry suits. For both the RME wet suit and dry suit scenarios, divers were assumed to contact in-water sediment and surface water for 25 years of employment with 5 days of exposure frequency per year. For the CT scenario, which only includes wet suit divers, divers were assumed to contact in-water sediment and surface water for 9 years of employment with 2 days of exposure frequency per year. The event duration for exposure to sediment and surface water for both diver scenarios was 4 hours per diver for the RME and 2 hours per diver for the CT exposure. Whole body exposure was assumed for the skin surface area for the wet suit diver scenario (RME and CT), so that the surface area for the exposed skin was 18,510 square centimeters (cm~~^{2}~~). For the skin surface area for the dry suit diver scenario (RME only), it was assumed that only the head and neck would be exposed, equivalent to a skin surface area of approximately 2,510 cm~~^{2}~~. The sediment dermal adherence factors for both diver exposure scenarios were the same as those for the in-water fishers. The sediment ingestion rates for both diver exposure scenarios were the same as the in-water fishers (RME of 50 mg/day and CT of 25 mg/day), though the sediment contact frequency term was not used for divers. The water ingestion rates for both diver exposure scenarios were the same as those used for the recreational beach swimmers. Tables 3-27 and 3-28 summarize exposure assumptions for the wet suit and dry suit divers for in-water sediment and surface water, respectively, and the reference or rationale for each value.~~

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~~5.3.1.8 Domestic Water Users~~

~~Surface water within the Study Area is not currently used as a domestic water source and there are no known plans to use it as a domestic water source in the future. However, the designated beneficial uses of the Willamette River include domestic water supply, assuming adequate pretreatment of the water prior to consumption. EPA specified that the BHHRA evaluate use of untreated river water as a domestic~~

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~~water supply. This scenario is considered hypothetical because pretreatment of surface water for domestic use would be required under current state laws.~~

Use of surface water as a household water source was evaluated assuming exposure occurs in a residential setting~~–~~. ~~To evaluate this hypothetical scenario, default EPA intake parameters for residential drinking water were used for both adult and child exposures.~~ Exposure ~~duration~~ frequency– ~~was~~ is assumed ~~to be~~as 350 days per year ~~for both adult and child residents~~(7 days/week for 50 weeks) for both the RME and CT evaluations~~–~~. As discussed in Section 3.5.9.5, overall exposure duration for residential exposure was assessed as 30 years for the RME estimate and 9 years for the CT estimate~~–~~. ~~The water ingestion rates used for both adult and child were those recommended for residential ingestion of drinking water (EPA 1989)~~Water ingestion by adults was evaluated at a rate of 2 L/day for the RME estimate, representing the average of the 90th percentiles of two national studies (EPA 1997a)~~–~~. A value of 1.4 L/day was used for the CT estimate, representing the population-weighted means of the same studies~~–~~. These values are representative of water consumed directly from the tap or used in the preparation of food and beverages for~~t~~ adults~~–~~. Ingestion rates representing 50th percentile values of 1.4 L/day for RME and 0.9 L/day for CT were used for children aged 6 years and younger~~–~~.

Dermal exposures during showering or bathing were evaluated assuming a rate of one event per day, with an event duration of 35 minutes (0.58 hr) for the RME and 15 minutes (0.15 hr) for the CT, representing the 95th and 50th percentile values from EPA 1997a~~–~~. A total skin surface area of 18,000 cm^2, representing estimates of the 50th percentile of mean surface area for adult men and women (EPA 1997a), was used for both the RME and CT estimates~~–~~. A corresponding mean surface area of 6,600 cm^2 was used for children aged 6 years and younger. ~~. The event duration and skin surface area were the recommended values for adults and children while showering or bathing (EPA 2004). Event frequency was once per day for both adult and child. None of the chemicals selected as COPCs for the domestic water use scenario were volatile, and therefore the inhalation exposure route was not evaluated for this scenario.~~

Table 3-30 summarizes the exposure assumptions ~~for the hypothetical domestic~~used to evaluate domestic use of surface water ~~water use by adult and child residents, and the reference or rationale for each value~~.

~~5.3.2~~3.5.11 Chemical-Specific Exposure Factors and Assumptions

In calculating chemical intakes, certain assumptions were made that were specific to a given chemical or class of chemicals~~–~~. These chemical-specific assumptions had an effect on both EPCs and intake calculations, and are described below.

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~~5.3.2.1 Exposure Point Concentrations~~Arsenic

3.5.11.1 ~~Calculations of EPCs are described in Section 3.4 and the resulting EPC values are presented in Tables 3-2 through 3-25.~~ . ~~Inorganic arsenic EPCs were estimated from total arsenic concentrations, as described below.~~ . ~~In addition, PCBs were summed in several different ways, as described below.~~

Although arsenic was analyzed as total arsenic, the~~, but the~~ toxicity values ~~for arsenic are only relevant~~represent ~~for~~ inorganic arsenic~~, which is most significant for tissue.~~ . . In previous fish tissue studies in the lower Columbia and Willamette Rivers, the percent of inorganic arsenic relative to total arsenic ranged from 0.1~~%~~ percent to 26.6~~%~~ percent with an average ~~average percent inorganic arsenic~~ of 5.3~~%~~ percent inorganic arsenic in ~~the~~ resident fish samples from the Willamette River (Tetra Tech 1995, EVS 2000)~~.~~. Shellfish may have a higher percentage of inorganic arsenic, as measured in studies on the Lower Duwamish River~~.~~. The Columbia River Basin Fish Contaminant Survey (EPA 2002c) concluded that a "value of 10~~%~~ percent is expected to result in a health protective estimate of the potential health effects from arsenic in fish." Therefore, ~~it was assumed that~~ 10~~%~~ percent of total arsenic in tissue was ~~in the form of~~assumed to be inorganic arsenic ~~for purposes of this BHHRA.~~ . ~~The total arsenic concentrations were multiplied by 10% percent and the resulting value was used in~~ when calculating ~~the tissue EPCs for arsenic.~~ . Uncertainties associated with the assumption that 10~~%~~ percent of the total arsenic is in the inorganic fo~~rm RM~~rm in fish and shellfish are discussed further in Section 6.

3.5.11.2 PCBs

PCBs were analyzed as Aroclors and congeners in tissue~~.~~. ~~For~~ Where PCBs were analyzed as Aroclors, the summed concentration of individual Aroclors was used in calculating the EPCs~~, as described in Attachment F2.~~ . ~~For~~ Where PCBs were analyzed as congeners, EPCs were calculated using both the total PCB value (sum of individual congeners) and an adjusted total PCB value~~.~~. The adjusted total PCB value was calculated by subtracting the concentration of the coplanar PCB congeners from the total PCB concentration~~.~~. This was done because the coplanar PCB congeners were evaluated separately (as TCDD toxic equivalents [TEQs]) for cancer risks~~.~~. Further explanation of how PCB congeners were summed is provided in as described in Section 2.2.8~~Attachment F2~~.

~~Lead~~

~~Health effects associated with exposure to inorganic lead and compounds are well documented and include neurotoxicity, developmental delays, hypertension, impaired hearing acuity, impaired hemoglobin synthesis, and male reproductive impairment. Importantly, many of lead's health effects may occur without other overt signs of toxicity. Lead has particularly significant effects in children, and it appears that some of these effects, particularly changes in the levels of certain blood enzymes and in aspects of children's neurobehavioral development, may occur at blood lead levels so low as to be essentially without a threshold. Because of the difficulty in accounting~~

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~~for pre-existing body burdens of lead and the apparent lack of threshold, EPA determined that it was inappropriate to develop a RfD. The Centers for Disease Control (CDC) has identified a blood lead concentration of 10 micrograms per deciliter (µg/dL) as the level of concern above which significant health effects may occur (CDC 1991), and the concentration of lead in the blood is used as an index of the total dose of lead regardless of the route of exposure (EPA 1994). An acceptable risk is generally defined as a less than 5 percent probability of exceeding a blood lead concentration of 10 µg/dL (EPA 1998).~~

~~Using the ALM (EPA 2003c), acceptable and the Integrated Exposure Uptake Biokinetic Model for Lead in Children (IEUBK, EPA 2007d), the Columbia River Basin Fish Contaminant Survey (EPA 2002c) calculated lead concentrations in fish tissue that are unlikely to result in fetal and childhood blood lead concentrations greater than 10 µg/dL were calculated using the following equation.~~

~~The following equations from the ALM were used in the Columbia River Basin Fish Contaminant Survey (EPA 2002c) to develop tissue concentrations to be protective of fetuses of tribal adults:~~

$$\cancel{PbF = \frac{\left(\left[PbB_f / R \times GSD^{1.645}\right] - PbB_o\right) \times AT}{BKSF \times \left(IR_F \times AF_F \times EF_F\right)}}$$

~~Where:~~

~~PbB_a = Central tendency of adult blood lead level~~
~~PbB_o = Adult baseline blood lead level~~
~~PbB_f = Fetal blood lead level~~
~~R = Fetal/maternal blood lead ratio~~
~~GSD = Geometric standard deviation PbB~~
~~BKSF = Biokinetic slope factor~~
~~PbF = Lead fish tissue concentration~~
~~IR_F = Fish tissue ingestion rateConsumption rate of fish~~
~~AF_F = GAbsolute gastrointestinal ingestionabsorption of lead from factor for ingested lead infish tissue~~
~~EF_F = Exposure frequency offor fish ingestionconsumption~~
~~AT = Averaging timetime~~

~~The EPA (2003c) ALM approach was used to determine protective fish tissue concentrations for the fetuses of both adult fishers and adult tribal fishers in the Study Area, using updated default ALM assumptions for the West Region, which are based on current EPA guidance (EPA 2003c). Differences in default parameter values from the EPA (2003c) application of the ALM to the ALM application for this BHHRA include a change in PbB_o from 2.2 µg/dl to 1.4 µg/dl, and a change in AF_F from 0.1 to 0.12.The values used in this analysis are presented in Attachment F5.~~

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~~The evaluation of risks from lead is based onBecause the lead models calculate a central tendency or geometric mean levelsblood lead concentration, and associated probabilities, so median values are generallytypically used as inputs to the equations. The mean estimate of national per capita fish consumption of 7.5 g/day (EPA 2000b) was used as the consumption rate for adultsrecreational fishers (EPA 2000b), t. The median consumption fish ingestion rate of 39.2 g/day from the CRITFC study was used for tribal fishers fishers is 39.2 g/day, as stated in the CRITFC Fish Consumption Survey (CRITFC 1994) and used by the EPA (2002c) in calculations of protective lead tissue concentrations. The ALM inputs and results for estimating protective lead tissue concentrations for fetuses of adult fishers and adult tribal fishers consuming fish in the Study Area are provided in Table F5-3 of Attachment F5.~~

~~Using the above equations presented above, the target lead concentrations in fish are, the ALM predicts that fetal blood lead levels will exceed 10 µg/dl less than 5 percent of the time for adult fishers at a lead fish tissue concentration of 5.25 mg/kg for recreational fishers and 1 mg/kg for tribal fishers.. The maximum fish tissue EPC for lead in the Study Area is 1,100 mg/kg, detected in a smallmouth bass whole body tissue sample. This is above the protective concentration of 5.25 mg/kg. However, this maximum EPC is orders of magnitude greater than all other resident fish EPCs and may be attributable to lead in the gut of the fish due to the ingestion of a metallic object (e.g., sinkers) (Integral 2008). There are no other resident fish tissue EPCs which exceed a protective lead concentration of 5.25 mg/kg. Therefore, while lead is considered a preliminary chemical potentially posing unacceptable risks for fish ingestion by an adult fisher, the uncertainties associated with the maximum detected concentration and evaluations of lead are discussed further in Section 6.~~

~~The protective lead tissue concentration for fetuses of tribal adults, using the above methods, is 1.01 mg/kg. The maximum fish tissue lead EPC for an adult tribal fisher is 23 mg/kg. However, the tribal fisher tissue ingestion scenario is for a multi-species diet consisting of both resident and anadromous species. There are no detected concentrations in anadromous species exceeding 1.01 mg/kg. Over 99% of the lead in the maximum lead EPC for tribal fishers is attributable to the Study Area-wide EPC for lead in smallmouth bass, which is influenced by the maximum EPC mentioned above for adult fishers. Therefore, while lead is considered a preliminary chemical potentially posing unacceptable risks for fish ingestion by an adult tribal fisher, the~~

~~EPA's Integrated Exposure Uptake Biokinetic (IEUBK) model was used to calculate tissue lead concentrations unlikely to result in blood lead concentrations greater than 10 µg/dL in children. Because site-specific values for concentration of lead in soil, house dust, air and drinking water were not readily available, default values were used for those inputs. The ratio of child-to-adult consumption rate of 0.42 was applied to the median adult consumption rate of 7.5 g/day to obtain a childhood rate of 3.2 g/day for children of recreational fishers. The corresponding lead concentrations in fish is 2.6 mg/kg. Assuming a tribal consuming tissue at aconsumption rate of 16.2~~

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~~g/day for tribal children, representing the 65th percentile consumption rate from the CRITFC survey, the calculated lead concentration in fish is 0.5 mg/kg. uUncertainties associated with the maximum detected concentration and evaluations of lead are discussed further in Section 6.~~

~~5.3.2.2 Dermal Absorption Factors for Sediment~~

~~1.0 EPA's Supplemental Guidance for Dermal Risk Assessment (2004) provides chemical-specific values for dermal absorption from contaminated soil. Dermal absorption of chemicals from soil adhered to the skin is dependent on a variety of factors, including the condition of the skin, the nature of adhered soil/sediment, and the chemical concentration. These chemical-specific dDermal absorption factors, representing the fraction of a chemical absorbed from soil or sediment adhered to the skin were used in the intake equations for dermal contact with sediment and are presented in Table 3-31. However, as noted in EPA guidance (2004), the amount of chemical absorbed from sediment may differ from that absorbed from soil due to differences in the relative importance of numerous chemical, physical, and biological factors. A default dermal absorption value was used for semi-volatile organic compounds (SVOCs) that do not have chemical-specific values. Per EPA guidance (2004), only those compounds or classes of compounds for which dermal absorption factors exist were evaluated quantitatively for the dermal contact exposure pathway. For compounds without dermal absorption factors, which are certain metals and perchlorate for the sediment COPCs, dermal intake was assumed to be zero. The uncertainties associated with chemicals lacking dermal absorption factors are discussed in Section Section 6.~~

~~3.1.1.4 Dermal Absorption Factors for Surface Water and Groundwater Seeps~~

~~2.0 One of the parameters in the intake equations for dermal contact with surface water or groundwater seeps is the absorbed dose per event (DA_{event}). This parameter was derived per EPA guidance (2004) using chemical-specific factors, which are presented in Table 3-32 for scenarios involving direct contact with surface water or groundwater seeps and in Table 3-33 for the hypothetical domestic water use scenario. The chemical-specific factors used in the calculation of DA_{event} were obtained from Appendix B (Screening Tables and Reference Values for the Water Pathway) of EPA's Supplemental Guidance for Dermal Risk Assessment (2004). The uncertainties associated with calculating DA_{event} for chemicals with factors outside of the predictive domain are discussed in Section 6.~~

~~3.1.1.5~~3.5.11.3 Oral Bioavailability Factors for Sediment

Consistent with EPA guidance (1989), the chemical intake equations calculate the amount of chemical at the human exchange boundaries, not the amount of chemical available for absorption. Therefore, the estimated intakes calculated in this BHHRA are not the same as the absorbed dose of a chemical. However, the toxicity of an ingested chemical depends on the degree to which the chemical is absorbed from the

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gastrointestinal tract into the body. Per EPA guidance (1989, 2007c), if the exposure medium in the risk assessment differs from the exposure medium assumed by the toxicity value, an adjustment for bioavailability may be appropriate. For purposes of this BHHRA, oral bioavailability factors were not used to adjust the estimated exposures from COPCs in sediment. The uncertainties associated with not considering bioavailability in this BHHRA are discussed in Section 6.

4.0 TOXICITY ASSESSMENT

The toxicity assessment is composed of two steps: (1) hazard identification and (2) dose-response assessment~~.~~. Hazard identification is the process of determining whether exposure to a chemical may result in a deleterious health effect in humans~~.~~. It consists of characterizing the nature of the effect and the strength of the evidence that the chemical will cause the observed effect~~.~~. Dose-response assessment characterizes the relationship between the dose and the incidence and/or severity of the adverse health effect in the exposed population. For risk assessment purposes, chemicals are generally separated into categories based on their toxicological endpoints~~.~~. The primary basis of this categorization is whether a chemical exhibits potentially carcinogenic or noncarcinogenic health effects~~.~~. Because chemicals that are suspected carcinogens may also give rise to noncarcinogenic effects, they must be evaluated separately for both effects~~.~~. ~~Toxicity values provide a quantitative estimate of the potential for adverse effects resulting from exposure to a chemical. Toxicity values are used in risk assessment to quantify the likelihood of adverse effects occurring at different levels of exposure to a chemical.~~

~~Toxicity values were identified for the COPCs that were selected in Section 2.4. The cancer and noncancer toxicity values are shown in Tables 4-1 and 4-2, respectively. The following sections discuss the toxicity values and describe how they were selected.~~

~~5.4~~4.1 TOXICITY VALUES FOR EVALUATING CARCINOGENIC EFFECTS~~TOXICITY VALUES~~

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Cancer slope factors are used to estimate the risk of cancer associated with exposure to a chemical known or suspected to be carcinogenic~~.~~. The slope factor is derived from either human epidemiological or animal studies, and represents an upper bound, generally approximating a 95 percent confidence limit, on the increased cancer risk from a lifetime exposure by ingestion~~.~~. Slope factors are generally expressed in units of proportion (of a population) affected per mg of substance/kg body weight-day ([(mg/kg-day)$^{-1}$].

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In addition to the numerical estimates of carcinogenic potential, a cancer weight-of-evidence (WOE) descriptor is used to describe a substance's potential to cause cancer in humans and the conditions under which the carcinogenic effects may be expressed. This judgment is independent of consideration of the agent's carcinogenic potency~~.~~. Under EPA's 1986 guidelines for carcinogen risk assessment, the WOE was described by categories "A through E"—Group A for known human carcinogens through Group E for agents with evidence of noncarcinogenicity~~.~~. Under EPA's 2005 guidelines for carcinogen risk assessment, a narrative approach rather than the alphanumeric categories is used to characterize carcinogenicity~~.~~. Five standard weight-of-evidence descriptors are used: *Carcinogenic to Humans, Likely to Be*

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Carcinogenic to Humans, Suggestive Evidence of Carcinogenic Potential, Inadequate Information to Assess Carcinogenic Potential, and Not Likely to Be Carcinogenic to Humans)~~.~~. ~~Slope factors (SFs) are used to quantify the dose-response potency of potential carcinogens. SFs are derived from either human epidemiological or animal studies by applying a mathematical model to the dataset to extrapolate from the high doses in studies to the lower exposure levels expected for human contact in the environment (EPA 1989). The SF is an upper-bound estimate or maximum likelihood estimate of the probability of a response over a lifetime.~~

~~Slope factors are available for oral and inhalation exposure pathways. The inhalation exposure pathway was not quantitatively evaluated in this BHHRA, so inhalation unit risk values were not selected as toxicity values. Dermal SFs~~Slope factors for assessing dermal exposure were derived ~~from the oral SFs,~~ as described in Section 4.7, and~~.~~ ~~The~~ oral and dermal ~~cancer~~ slope factors are presented in Table 4-1~~.~~. ~~In accordance with EPA (2005a) guidance, the weight of evidence for carcinogenicity for each COPC is also presented in Table 4-1.~~

~~5.5~~4.2 TOXICITY VALUES FOR EVALUATING NONCARCINOGENIC EFFECTS~~TOXICITY VALUES~~

The reference dose (RfD) provides quantitative information for use in risk assessments for health effects known or assumed to be produced through a nonlinear (possibly threshold) mode of action. The RfD, expressed in units of mg of substance/kg body weight-day (mg/kg-day) is defined as an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime~~.~~. The use of RfDs is based on the concept that there is range of exposures that exist up to a finite value, or threshold, that can be tolerated without producing a toxic effect~~.~~. ~~Because EPA has not derived toxicity values specific to skin contact, dermal RfDs were derived in accordance with EPA's Supplemental Guidance for Dermal Risk Assessment (EPA 2004). The RfD that reflects the absorbed dose was calculated by using the following equation:~~

$$\cancel{RfD_{dermal} = RfD_o \times ABS_{GI}}$$

~~RfD_{dermal} = dermal reference dose (mg/kg-day)~~

~~RfD_o = child exposure duration (years)~~

~~ABS_{GI} = adult exposed skin surface area (cm^2)~~

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~~Most toxicity values are based on either oral or inhalation exposures. For oral exposures, toxicity values are often expressed as the amount of substance administered, whereas dermal exposures are expressed as absorbed dose.~~

~~As recommended by EPA guidance (EPA 2004), an adjustment to the oral toxicity factor to account for the estimated absorbed dose was applied in this BHHRA when the following conditions are met:~~

~~The toxicity value derived from the critical study is based on an administered dose (e.g., through diet or by gavage)~~

~~A scientifically defensible database demonstrates the GI absorption of the chemical is less than 50 percent in a medium similar to the one used in the critical study.~~

~~If both of these conditions are met, the oral toxicity factor was adjusted to reflect the absorbed dose in this BHHRA. For carcinogenic effects, the oral slope factor was divided by the GI absorption factor to estimate the dermal slope factor. Hexavalent chromium was the only COPC for which the oral slope factor was adjusted to reflect the absorbed dose. For noncarcinogenic effects, the oral reference dose was multiplied by the GI absorption factor to estimate the dermal reference dose. The COPCs for which the oral reference dose was adjusted to reflect the absorbed dose are the metals: antimony, barium, cadmium, trivalent chromium, hexavalent chromium, manganese, mercury, silver, and vanadium.~~

~~If both conditions for adjustment are not met, the oral toxicity value was used as a surrogate for the dermal toxicity value in the BHHRA. Dermal toxicity factors are presented in Tables 4-1 and 4-2.~~

~~EPA recommends adjusting oral toxicity values only when evidence suggests that GI absorption is less than 50 percent. GI absorption efficiencies were obtained from the Supplemental Guidance for Dermal Risk Assessment (EPA 2004). A chemical that exhibits adverse effects other than cancer or mutation-based developmental effects is believed to have a threshold (i.e., a dose below which no adverse effect is expected to occur). Reference doses (RfDs) are typically used as toxicity values for chemicals with noncarcinogenic effects. A chronic RfD is defined as a daily dose to which humans, including sensitive subpopulations, may be exposed throughout their lifetimes without adverse health effects.~~

~~Reference doses are available for oral and inhalation exposure pathways. The inhalation exposure pathway was not quantitatively evaluated in this BHHRA, so inhalation reference concentrations were not selected as toxicity values. Dermal reference doses were derived from oral reference doses, as described in Section 4.7.~~ Reference doses ~~for oral and dermal exposure pathways~~ are presented in Table 4-2.

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~~5.6~~4.3 SOURCES OF TOXICITY VALUES

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The following hierarchy of sources of toxicity values is currently recommended for use at Superfund sites (EPA 2003b):

- Tier 1 – EPA's Integrated Risk Information System (IRIS) database (EPA 2010b) is the preferred source of information because it normally represents the official EPA scientific position regarding the toxicity of the chemicals based on the data available at the time of the review~~.~~. IRIS contains RfDs and cancer slope factor (SFs) that have gone through a peer review and EPA consensus review.
- Tier 2 - EPA's Provisional Peer Reviewed Toxicity Values (PPRTVs) are toxicity values derived for use in the Superfund Program when such values are not available in IRIS~~.~~. PPRTVs are derived after a review of the relevant scientific literature using the methods, sources of data and guidance for value derivation used by the EPA IRIS Program~~.~~. The PPRTV database includes RfDs and SFs that have undergone internal and external peer review~~.~~. The Office of Research and Development/National Center for Environmental Assessment/Superfund Health Risk Technical Support Center (STSC) develops PPRTVs on a chemical-specific basis when requested by EPA's Superfund program.
- Tier 3 - Tier 3 includes additional EPA and non-EPA sources of toxicity information~~.~~. Priority is given to those sources of information that are the most current, the basis for which is transparent and publicly available, and which have been peer reviewed~~.~~. Tier 3 sources may include, but need not be limited to, the following sources:

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  - The California Environmental Protection Agency (Cal EPA) Toxicity Criteria Database (Cal EPA 2008) includes toxicity values that have been peer reviewed~~.~~.
  - The ATSDR Minimal Risk Levels are similar to RfDs and are peer reviewed~~.~~.
  - Health Effects Assessment Summary Table (HEAST) toxicity values are currently under review by the STSC to derive PPRTVs~~.~~. The toxicity values remaining in HEAST are considered Tier 3 values.

~~Toxicity values were retrieved from the most current version of the Regional Screening Levels for Chemical Contaminants at Superfund Sites (EPA 2010a, values updated November 2010. These values follow the above hierarchy, and present toxicity values from IRIS for both noncarcinogenic and carcinogenic effects were selected when available. If a toxicity value is not available from IRIS, toxicity values from the PPRTV database are presented, if available. In the absence of toxicity values from either IRIS or the PPRTV database, toxicity values from Tier 3 sources are presented, if available. The sources of the cancer or noncancer toxicity value are indicated in Tables 4-1 and 4-2. The dates shown in Tables 4-1 and 4-2 indicate the~~

~~date of release of the Regional Screening Levels for Chemical Contaminants at Superfund Site table (EPA 2010a).~~

T~~For t~~richloroethylen~~e~~e cancer potency was evaluated ~~,~~using ~~EPA provided the draft toxicity value equal to~~ the geometric mid-point of the slope factor range from ~~(~~EPA 2001b as recommended by EPA Region 10 (EPA 2007b)~~) to use as the oral cancer slope factor~~. Recommendations were not provided for evaluating oral exposures for noncancer endpoints for trichloroethylene.

~~5.7~~4.4 CHEMICALS WITH SURROGATE TOXICITY VALUES

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I~~For some chemicals, i~~f a toxicity value was not available from the above hierarchy for a specific chemical, a structurally similar chemical was identified as a surrogate~~. ~~. The reference dose or slope factor for the surrogate chemical was selected as the toxicity value and the surrogate chemical was indicated in Tables 4-1 and 4-2~~. ~~. The following chemicals ~~have toxicity values from surrogate chemicals~~were evaluated using surrogate toxicity criteria:

- Butyltin~~ ion. ~~. The toxicity of organotin compounds is somewhat determined by the nature and number of groups bound to tin~~. ~~. In general, toxicity decreases as the number of linear carbons increases and as the number of substitutions decrease~~,~~.~~oxicity values were identified from the recommended hierarchy for dibutyltin compounds and tributyltin compounds. Toxicity of alkyltin compounds depends on the number of alkyl side-chains, with monoalkyl tin being the least and trialkyl tin the most toxic (National Library of Medicine [NLM] 2004). Therefore, dibutyltin is thought to be more similar to butyltin than tributyltin in toxicity, and is more toxic than butyltin.~~ As a health protective approach, ~~the toxicity value~~RfD for dibutyltin compounds was selected as a surrogate for butyltin~~ ion~~.

- ~~Dibutyltin ion. The available toxicity value for dibutyltin is for dibutyltin compounds. However, the BHHRA sample results were for dibutyltin ion. The dibutyltin compounds toxicity value was selected as a surrogate for dibutyltin ion.~~

- ~~Tributyltin ion. The available toxicity value for tributyltin is for tributyltin compounds. However, the BHHRA sample results were for tributyltin ion. The tributyltin compounds toxicity value was selected as a surrogate for tributyltin ion.~~

- Acenaphthylene ~~. IRIS~~ is ~~classifies~~ classified ~~acenaphthylene~~ as ~~a~~ category D ~~carcinogen~~ (not classifiable as to human carcinogenicity)~~, and therefore, is considered a noncarcinogenic polycyclic aromatic hydrocarbon (PAH).~~ . The RfD for ~~Acenaphthene~~ acenaphthene, which is the ~~noncarcinogenic PAH~~ most structurally similar PAH~~in structure and carbon number to acenaphthylene.~~

~~Therefore, the acenaphthene toxicity value~~, was selected as a surrogate for acenaphthylene.

- Benzo(e)pyrene~~. –~~. ~~IRIS classifies benzo(e)pyrene as a category D carcinogen (not classifiable as to human carcinogenicity), and therefore, is considered a noncarcinogenic PAH. O~~As a health protective approach, the RfD for p~~f the noncarcinogenic PAHs most similar in structure and carbon number to benzo(e)pyrene, p~~yrene ~~has the lowest toxicity value and is therefore, considered the most toxic. As a health protective approach, the pyrene toxicity value~~ was ~~selected~~ used as a surrogate for benzo(e)pyrene.

- Benzo(g,h,i)perylene~~. IRIS classifies benzo(g,h,i)perylene~~ is classified as ~~a~~ category D ~~carcinogen~~ (not classifiable as to human carcinogenicity)~~, and therefore, is considered a noncarcinogenic PAH.~~ As with benzo(e)pyrene, ~~Of the noncarcinogenic PAHs most similar in structure and carbon number to benzo(g,h,i)perylene, pyrene has the lowest toxicity value and is therefore, considered the most toxic. As a health protective approach, the pyrene~~the RfD for pyrene ~~toxicity value~~ was ~~selected~~ used as a surrogate for benzo(g,h,i)perylene.

- Dibenzothiophene~~. –~~. ~~Toxicity values were not available for dibenzothiophene. The chemical with~~ Fluorene the most ~~similar~~ structur~~e~~ally similar PAH with available toxicity values ~~is fluorene. –~~. Hence, t~~T~~he ~~toxicity value~~RfD for fluorene was ~~selected~~ used as a surrogate for dibenzothiophene.

- Dibenzofuran~~. –~~. The RfD for flourene, which represents the most structurally similar compound ~~oxicity values were not available for dibenzofuran. The chemical with the most similar structure with available toxicity values is fluorene. The toxicity value for fluorene~~for which an RfD was available was selected as a surrogate for dibenzofuran.

- Di-n-octyl phthalate~~. –~~. ~~Toxicity values were not available for di-n-octyl phthalate. The chemical with the most similar structure with available toxicity values is dibutyl phthalate.~~ The RfD for ~~toxicity value for~~ dibutyl phthalate was selected as a surrogate for di-n-octyl phthalate.

- Perylene~~. –~~. ~~IRIS classifies perylene as a category D carcinogen (not classifiable as to human carcinogenicity), and therefore, is considered a noncarcinogenic PAH. Of the noncarcinogenic PAHs similar in structure and carbon number to perylene, pyrene has the lowest toxicity value and is therefore, considered the most toxic. As a health protective approach, the~~The RfD for pyrene ~~toxicity value~~ was selected as a surrogate for perylene.

- Phenanthrene~~. –~~. ~~IRIS classifies phenanthrene as a category D carcinogen (not classifiable as to human carcinogenicity), and therefore, is considered a~~

~~noncarcinogenic PAH. Of the noncarcinogenic PAHs similar in structure and carbon number to phenanthrene, pyrene has the lowest toxicity value and is therefore, considered the most toxic. As a health protective approach, the~~The RfD for pyrene ~~toxicity value~~ was selected as a surrogate for phenanthrene.

- Retene. ~~Retene is a PAH classified by IRIS as a category D carcinogen (not classifiable as to human carcinogenicity). Of the noncarcinogenic PAHs similar in structure and carbon number to retene, pyrene has the lowest toxicity value and is therefore, considered the most toxic. As a health protective approach, the~~ The RfD for pyrene ~~toxicity value~~ was selected as a surrogate for retene.

- Endrin aldehyde~~—~~. Endrin aldehyde can occur as an impurity of endrin or as a degradation product (ATSDR 1996)~~—~~. The ~~toxicity value~~RfD for endrin was ~~selected~~ used as a surrogate for endrin aldehyde.

- Endrin ketone~~—~~. Endrin ketone can occur as an impurity of endrin or as a degradation product (ATSDR 1996)~~—~~. The ~~toxicity value~~ RfD for endrin was ~~selected~~ used as a surrogate for endrin ketone.

- 4-Nitrophenol~~—~~. ~~IRIS has toxicity values for 2-methylphenol and 4-methylphenol, but not 4-nitrophenol.~~ The ~~toxicity value~~RfD for 4-methylphenol was ~~selected~~ used as a surrogate for 4-~~-~~nitrophenol.

~~5.8~~4.5 CHEMICALS WITHOUT TOXICITY VALUES

No SF and RfD~~,~~ or other suitable surrogate values were obtained for ~~Only two COPCs,~~ titanium and delta-hexachlorocyclohexane (delta-HCH)~~, did not have available SF and RfD toxicity values or appropriate surrogate chemicals from sources included in the hierarchy.~~ ~~—~~. Titanium is a naturally occurring element and has been characterized as having extremely low toxicity (Friberg et al. 1986)~~—~~. An STSC review concluded that the other hexachlorocyclohexane isomers could not be used as surrogates for delta-HCH due to differences in toxicity (EPA 2002d)~~—~~. Accordingly, t~~In this BHHRA, t~~he potential risks from titanium and delta-HCH are discussed qualitatively in the uncertainty assessment in Section 6.

SFs and RfDs were not identified for lead because lead was evaluated through comparison with benchmark concentrations that are based on blood lead levels~~—~~. Benchmark concentrations for child exposure scenarios were predicted by the Integrated Exposure Uptake Biokinetic (IEUBK) model~~—~~. Benchmark concentrations for adult exposure scenarios were predicted by the Adult Lead Methodology (ALM). Uncertainties associated with using these benchmark concentrations are discussed in Section 6.4.4.

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~~5.9~~4.6 TOXICITY VALUES FOR CHEMICAL ~~MIXTURES~~CLASSES

~~Some~~ Certain toxicity values are based on exposure to ~~chemical mixtures~~more than one isomer and not to individual chemicals~~.~~. As a result, the risks were evaluated for the combined exposure ~~to the chemicals and not on~~rather than on an individual chemical basis~~.~~. ~~The chemicals~~COPCs that were evaluated for toxicity as ~~mixtures~~ classes are indicated in Tables 4-1 and 4-2, and are discussed below~~.~~.

- Chlordane~~.~~: The chlordane toxicity values were derived for technical chlordane, which is composed of a mixture of chlordane isomers~~.~~. The chlordane isomers analyzed in Round 1, Round 2, and Round 3 samples were alpha-chlordane, *trans*-chlordane, *cis*-nonachlor, *trans*-nonachlor, and oxychlordane~~.~~. These isomers were summed in a total chlordane concentration~~.~~. The SF and RfD for technical chlordane were used to evaluate total chlordane.

- DDD, DDE, and DDT~~.~~: Technical DDT includes 2,4'~~’~~-DDT and 4,4'~~’~~-DDT, as well as 2,4'~~’~~-DDE, 4,4'~~’~~-DDE, 2,4'~~’~~-DDD, and 4,4'~~’~~-DDD~~.~~. Although individual slope factors are available for DDD, DDE, and DDT~~-~~ based on studies conducted using the ~~have separate SFs included in IRIS. While the SFs were derived for the~~ 4,4'~~’~~ isomers, ~~the SFs were used to evaluate the sum of the~~the potency of the 2,4'~~’~~ ~~and~~ isomers was assumed to be equal to that of the 4,4'~~’~~ isomers~~,~~, and cancer risks assessed as the sum of the 2,4' and 4,4' isomers~~because toxicity values are not available for the 2,4’ isomers.~~. ~~The~~ Additionally, the ~~DDT~~ RfD for DDT ~~was derived for a mixture of the 2,4’ and 4,4’ isomers and was used to evaluate the noncancer endpoint of DDT. As an RfD is not available for the DDD or DDE isomers, so the DDT RfD~~ was ~~selected~~ used as a surrogate ~~toxicity value and was used~~ to evaluate the noncancer ~~endpoint~~ effects of DDD and DDE.

- Endosulfan~~.~~: The ~~toxicity value (~~RfD~~)~~ for endosulfan was derived from studies using technical endosulfan, which includes alpha-endosulfan, beta-endosulfan, and endosulfan sulfate~~.~~. The individual endosulfan results ~~These compounds~~ were summed ~~in~~ to give a total endosulfan concentration, and t~~.~~ ~~T~~he RfD for technical endosulfan was used to evaluate total endosulfan.

- PCBs~~.~~: ~~The PCB cancer SF was derived for PCB mixtures~~The cancer slope factor for PCBs is based on administered doses of Aroclors (Aroclor 1016, 1242, 1254, or 1260) ~~to rats. The cancer SF~~, and was ~~applied to~~ used to assess the cancer risks for total PCBs~~,~~ measured either as congeners or Aroclors~~.~~. As discussed in Section 2.2.8, total PCB concentrations were calculated as either the sum of Aroclors or individual congeners~~.~~. ~~The~~ Where PCBs were reported as individual congeners, ~~PCB SF was applied to the~~an adjusted PCB concentration was calculated ~~total PCB~~ by subtracting the sum of total dioxin-like PCB congener concentrations from the sum of all congeners~~congener concentration after subtracting the total dioxin-like PCB~~

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~~congener concentration.~~ . Dioxin-like PCB congeners ~~concentrations~~ were evaluated separately using the slope factor for 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD) ~~SF,~~ as described below ~~for dioxins and furans.~~ . This approach may double-count a portion of the toxicity of the dioxin-like PCBs, as discussed in Section 6.3.6~~.~~. The RfD for Aroclor 1254 ~~RfD~~ was used to evaluate the noncancer endpoint for total PCBs, measured either as total unadjusted congeners or as Aroclors.

- Dioxins and furans~~.~~: Toxic Equivalency Factors (TEFs) from the World Health Organization (WHO) (Van den Berg 2006) were used to evaluate carcinogenic effects of dioxin and furan congeners and for dioxin-like PCB congeners (see Table 4-3)~~.~~. Concentrations of individual congeners are multiplied by their respective TEF~~s~~ to provide a ~~estimate the toxicity of these congeners relative to~~ 2,3,7,8-TCDD-equivalant concentration (TEQ),~~;~~ the resulting ~~concentrations~~ TEQs are then summed into a total 2,3,7,8-TCDD ~~TEQ~~TEQ~~.~~. ~~The~~ Cancer risk were assessed using the slope factor for 2,3,7,8-TCDD ~~SF~~ was used to evaluate the cancer endpoint of the TEQ for dioxin and furan congeners, as well as ~~and~~ for dioxin-like PCB congeners~~.~~. The ATSDR MRL for 2,3,7,8-TCDD ~~RfD~~ was used ~~with the same approach to evaluate the noncancer endpoint of the~~in conjunction with the TEQ approach for dioxin and furan congeners, and for dioxin-like PCB congeners.

- Carcinogenic PAHs~~.~~: ~~Carcinogenic~~ Individual carcinogenic PAHs ~~can be~~were evaluated for toxicity based on their potency equivalency factor (PEF), which estimates ~~toxicity~~ cancer potency relative to benzo(a)pyrene (EPA 1993)~~.~~. The toxicity values for individual PAHs shown in Table 4-1 incorporate their respective PEFs~~.~~. Risk from both individual and total carcinogenic PAHs was assessed in this BHHRA.

~~5.10~~4.7 DERMAL ~~TOXICITY~~ ASSESSMENT

Toxicity is a function of contaminant concentration at critical sites-of-action~~.~~. However, most oral reference doses and slope factors are expressed ~~Most toxicity values are based on either oral, not dermal, or inhalation exposures. TFor oral exposures, toxicity values for oral exposure are often expressed as the amount of substancebased on~~as an administered ~~rather than an absorbed~~ dose, whereas exposure estimates for dermal exposures are ~~expressed as~~based on the absorbed dose~~.~~. Anatomical differences between the gastrointestinal tract and the skin can affect rate as well as the extent of absorption~~.~~. Thus, the route of exposure may significantly affect the critical dose at the site-of-action~~.~~. A further complication is that an orally administered dose experiences “hepatic first-pass” metabolism, ~~and~~ which may significantly alter the toxicity of the administered chemical~~.~~. ~~Gastrointestinal and pulmonary tracts is typically much greater than absorption through intact skin. Thus, for evaluating the effects of dermal exposure to contaminants in soil, it may be necessary to adjust the oral toxicity value from an administered dose to an absorbed dose by accounting for the absorption efficiency of the chemical.~~

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~~However~~Additionally,~~,~~ some chemicals can cause cancer or other effects through direct action at the point of application~~.~~. For such locally active compounds, it may be inappropriate to evaluate risks based on oral response data~~.~~. ~~EPA has developed a simplified method for oral-to-dermal extrapolations (EPA 2004). These extrapolations involve an adjustment to the oral toxicity value based on the GI absorption factor of the specific chemical in the same administration vehicle (e.g., corn oil, food) as used in the critical toxicity study to derive an estimated dermal dose.~~

As recommended by EPA guidance (EPA 2004), an adjustment to the oral toxicity factor to account for the estimated absorbed dose was applied ~~in this BHHRA~~ when t~~he following conditions are met:~~

~~•~~ ~~T~~he toxicity value derived from the critical study ~~is~~ was based on an ~~administered~~ oral dose ~~(e.g., through diet or by gavage)~~and

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~~•~~ ~~A scientifically defensible database demonstrates the~~ GI absorption of the chemical is less than 50~~%~~ percent ~~in~~ from a medium similar to the one used in the critical study.

~~If both of these conditions are met, the oral toxicity factor was adjusted to reflect the absorbed dose in this BHHRA~~Dermal RfDs for assessing dermal exposure ~~that~~ were calculated ~~by~~ using the following equation:

$$RfD_{dermal} = RfD_o \times ABS_{GI}$$

RfD_{dermal} = dermal reference dose (mg/kg-day)
RfD_o = child exposure duration (years)
ABS_{GI} = ~~adult exposed skin surface area (cm^2)~~fraction of contaminant absorbed in gastrointestinal tract

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Cancer slope factors for assessing dermal exposure were calculated as follows:

$$SF_{dermal} = \frac{SF_o}{ABS_{GI}}$$

SF_{dermal} = dermal cancer slope factor $(mg/kg\text{-}day)^{-1}$
SF_o = oral cancer slope factor $(mg/kg\text{-}day)^{-1}$
ABS_{GI} = fraction of contaminant absorbed in gastrointestinal tract

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~~. For carcinogenic effects, the oral slope factor was divided by the GI absorption factor to estimate the dermal slope factor. Hexavalent chromium was the only COPC~~

~~for which the oral slope factor was adjusted to reflect the absorbed dose. For noncarcinogenic effects, the oral reference dose was multiplied by the GI absorption factor to estimate the dermal reference dose. The COPCs for which the oral reference dose was adjusted to reflect the absorbed dose are the metals: antimony, barium, cadmium, trivalent chromium, hexavalent chromium, manganese, mercury, silver, and vanadium.~~

~~If both conditions for adjustment are not met, the oral toxicity value was used as a surrogate for the dermal toxicity value in the BHHRA. Dermal toxicity factors are presented in Tables 4-1 and 4-2.~~

5.0 RISK CHARACTERIZATION

Risk characterization integrates the information from the exposure assessment and toxicity assessment, using a combination of qualitative and quantitative information~~.~~ ~~.~~to provide numerical estimates of potential adverse health effects~~With this information, risk characterization estimates the potential health risk, based on the dose of a chemical, that a person may receive under certain site-specific exposure conditions and based on the toxicity of that chemical.~~ . Risk characterization is performed separately for carcinogenic and noncarcinogenic effects~~.~~. Carcinogenic risk is expressed as the probability that an individual will develop cancer over a lifetime as a result of exposure to a potential carcinogen~~.~~. Noncarcinogenic hazards are evaluated by comparing an estimated exposure level or dose with a reference dose that is without appreciable risk of adverse health effects.

~~3.0 Consistent with DEQ (DEQ 2000a) and EPA guidance (EPA 1989), noncarcinogenic and carcinogenic effects were evaluated separately. To characterize potential noncarcinogenic effects, comparisons were made between projected intakes of substances and toxicity values (Section 5.1.1). To characterize potential carcinogenic effects, projected intakes and chemical-specific, dose-response data were used to estimate the probability that an individual will develop cancer over a lifetime of exposure (Section 5.1.2).~~

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~~5.1~~~~1~~5.1 RISK CHARACTERIZATION ~~ESTIMATES~~METHODOLOGY

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This section describes how noncancer hazards and cancer risks were estimated in this BHHRA~~.~~ .

~~5.1~~~~1.1~~5.1.1 Noncancer Hazard Estimates

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The potential for adverse noncancer health effects ~~resulting from exposure to chemicals with noncarcinogenic effects~~ is generally addressed by comparing the CDI ~~or absorbed dose for a specific COPC~~ to ~~its~~ the ~~RfD. This comparison was made by calculating the ratio of the estimated CDI (or absorbed dose) to the~~ corresponding RfD to yield a hazard quotient (HQ~~):~~ ; EPA 1989):

$$HQ = \frac{CDI}{RfD}$$

The calculation of a HQ~~s~~ assumes that exposures less than the RfD are unlikely to result in adverse health effects, even for sensitive populations~~.~~. By definition, when the HQ is less than 1, the estimated exposure is less than the RfD and adverse health effects are unlikely~~.~~. Unlike cancer risks, the HQ does not represent a statistical probability, and the likelihood of adverse effects does not increase ~~linearly~~in a linear fashion relative to a HQ of 1~~.~~. Rather, exposures greater than the RfD may result in

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adverse health effects, but all RfDs do not have equal precision and are not based on the same severity of effects~~.~~. HQs for individual chemicals were summed to yield a cumulative hazard ~~indices~~ index (HIs) ~~that provides an estimate of total hazard.~~ . ~~Per EPA guidance (1989), HQs should only be summed for chemicals with common toxicological endpoints. Toxicological endpoints for COPCs are summarized in Table 5-1. Endpoint-specific HIs (e.g., neurological or immune system effects) were calculated for each exposure area in this BHHRA where the cumulative HI was greater than 1. The Columbia River Fish Contaminant Study performed a similar analysis for fish tissue collected from the Columbia River Basin (EPA 2002c). Toxicity endpoints were retrieved from EPA's Integrated Risk Information System (EPA 2010b), and may differ from the endpoints used in CRITFC due to updates in the IRIS database since the CRITFC study.~~Although a HI provides an overall indication of the potential for noncancer hazards, dose additivity is most appropriately applied to chemicals that induce the same effect via the same mechanism of action~~.~~. When the HI is greater than- 1 due the sum of several HQs of similar value, it is appropriate to segregate the chemical-specific HQs by effect and mechanism of action~~.~~. In this BHHRA, when the calculated HI was greater than 1, HQs based on the same target organ system were calculated~~.~~. The target organs or systems on which the RfDs are based are presented in Table 5-1.

~~4.0 Estimated HIs were compared to a target HI of 1, below which remedial action at a Superfund site is generally not warranted (EPA 1991a).~~

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~~5.11.2~~5.1.2 Cancer Risk Estimates

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The cancer slope factor converts the estimated daily intakes averaged over a lifetime directly to an incremental cancer risk~~.~~. C~~Potential c~~ancer risks ~~were assessed~~are calculated by multiplying the estimated LADI ~~or absorbed dose~~ of a carcinogen by ~~its~~ the SF (EPA 1989):~~. This calculated risk is expressed as the probability of an individual developing cancer over a lifetime as a result of exposure to the potential carcinogen, and is a health protective estimate of the incremental probability of excess individual lifetime cancer risk.~~

$$Risk = LADI \times SF$$

The dose-response relationship is generally assumed to be linear through the low-dose portion of the dose-response curve~~.~~. That is, the risk of developing cancer is assumed to be directly associated with the amount of exposure~~.~~. ~~Initially, potential cancer risks were estimated separately for each chemical. The separate potential cancer risk estimates were summed across chemicals for each exposure area to obtain the cumulative excess lifetime cancer risk for the exposure scenario.~~

However, this linear relationship is valid only when the estimated risk is less than 0.01 (1 x 10^{-2})~~0.01.~~. Where contaminant concentrations result in an estimated risk greater than 1 x 10^{-2}, the following equation was used (EPA, 1989):

$Risk = 1\text{-}e^{-LADI \times SF}$ ~~Cancer risks were calculated using this same linear model, even though risk estimates for some scenarios exceed 1 x~~ x ~~10~~$^{-2}$~~, in which case, EPA guidance (EPA 1989) states that risks should be calculated using an exponential model. Where cancer risks exceeded 1 x~~ x ~~10~~$^{-2}$~~, the exponential model was used.~~

~~Estimated total cancer risks were compared to 1 x~~ x ~~10~~$^{-4}$~~, 1 x~~ x ~~10~~$^{-5}$~~, and 1 x~~ x ~~10~~$^{-6}$ ~~cancer risk targets based upon the following language in EPA's National Contingency Plan (NCP): "For known or suspected carcinogens, acceptable exposure levels are generally concentration levels that represent an excess upper bound lifetime cancer risk to an individual of between 1 x~~ x ~~10~~$^{-4}$ ~~and 1 x~~ x ~~10~~$^{-6}$~~." The point of departure for cancer risks is 1 x~~ x ~~10~~$^{-6}$~~.~~ Because the slope factor typically represents an upper confidence limit, carcinogenic risk estimates generally represent an upper-bound estimate, and EPA is confident that the true risk will not be greater than risk estimates obtained using this model, and they may be less than that predicted~~.~~. Cancer risk estimates for individual chemicals and different exposure pathways were summed where exposure was assumed to be concurrent to obtain the cumulative excess lifetime cancer risk for each receptor and/or exposure scenario~~.~~.

~~5.11.3 Combined Adult/Child Scenarios~~

~~5.0 Cancer risks were calculated separately for adult and child receptors for the recreational beach user and fisher scenarios. To assess risks to individuals exposed as both a child and an adult, cancer risks were also calculated for a combined adult and child receptors for the recreational beach user and fisher scenarios. The combined adult and child receptor was based on EPA guidance (1991b, 2010a), in which 6 years of exposure is assumed to occur as a child and 24 years of exposure is assumed to occur as an adult for a total of 30 years for the non-tribal fisher scenario and the RME exposure duration for the beach user scenario. For the tribal fisher scenario, the combined adult and child scenario assumed 6 years of exposure as a child and 64 years of exposure as an adult. For the CT exposure duration for the beach user scenario, the combined adult and child scenario assumed 6 years of exposure as a child and 9 years of exposure as an adult.~~

~~For chemicals not acting by a mutagenic mode of action (i.e., all chemicals evaluated in this BHHRA other than carcinogenic PAHs), the cancer risks for the combined adult and child receptor were calculated by adding the cancer risks for the adult to the cancer risks for the child. For the non-tribal fisher and the RME beach sediment exposure scenarios, the adult cancer risk was multiplied by a factor of 24/30 to account for the 24 years of exposure as an adult in the combined scenario versus the 30 years used in the adult only scenario and then added to the child cancer risk. For the tribal fisher scenario, the adult cancer risk was multiplied by a factor of 64/70 to account for the 64 years of exposure as an adult in the combined scenario versus the 70 years used in the adult only scenario and then added to the child cancer risk.~~

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~~For chemicals acting by a mutagenic mode of action (i.e., carcinogenic PAHs), the cancer risks were calculated for the combined adult and child receptor by incorporating EPA's guidance (2005b) on early life exposures to carcinogens. Specifically, age dependent adjustment factors (ADAFs) were used to account for the increased carcinogenic potency during early life exposures. For ages 0 to 2 years, an ADAF of 10 was used. For ages 2 to 6 years and 6 to 16 years, an ADAF of 3 was used. For ages over 16 years, an ADAF of 1 was used. The ADAFs were incorporated into the risk calculations through the use of age adjusted factors. The exposure factors used for the ages 0 to 2 and 2 to 6 years were the same as the child receptor and the exposure factors used for the ages 6 to 16 years and over 16 years were the same as the adult receptor.~~

~~6.0 The cancer risk estimates for the combined adult and child receptor are presented in the beach sediment and fish consumption risk characterization results below.~~

~~5.11.4~~5.1.3 Infant Consumption of Human Milk

As discussed in Section 3.3.7, infant exposure to persistent, lipophilic contaminants via breastfeed was quantitatively evaluated in the BHHRA~~.~~. Using the methodology presented in Section 3.5.5, DEQ determined that the magnitude of the difference in the risk and hazard estimates between the infant and the mother remain constant regardless of the maternal exposure pathway or dose, and can be expressed as~~For bioaccumulative chemicals, exposure to the mother can lead to the presence of those chemicals in human milk, which can pose a risk to breastfeeding infants. Per agreement with EPA and DEQ, risks to infants through the consumption of human milk were included for all receptors where PCBs, dioxins, and/or DDX were identified as COPCs. Risks were assessed in accordance with DEQ guidance (2010).~~

~~To assess risks to infants,~~ infant risk adjustment factors (IRAFs~~)~~, DEQ 2010) ~~were applied to the mother's risk~~ where:

$$Risk_{infant} = Risk_{mother} \times IRAF_{ca}$$

$$HQ_{infant} = HQ_{mother} \times IRAF_{nc}$$

where:

HQ_{infant} = hazard quotient for breast-~~-~~fed infant
HI_{mother} = hazard quotient for the mother
$Risk_{infant}$ = cancer risks to breast-~~-~~fed infant
$Risk_{mother}$ = cancer risks to the mother
$IRAF_{ca}$ = infant risk adjustment factor for carcinogenic effects
$IRAF_{nc}$ = infant risk adjustment factor for noncancer effects

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~~. For~~ Where combined child and adult exposures were evaluated~~cancer risks~~, the combined ~~adult~~ child/adult ~~and child~~ risks were used ~~for~~ as the ~~mother~~ maternal cancer risk for assessing risks to infants~~receptors where both adult and child exposures could occur.~~ . ~~C~~The chemical-specific IRAFs ~~used~~ are presented in the following table:

Chemical	$IRAF_{ca}$	$IRAF_{nc}$
PCBs	1	25
Dioxins/Furans	1	2
DDx	0.007	2
PBDEs	1	2

5.1.4 Risk Characterization for Lead

Health effects associated with exposure to inorganic lead and compounds are well documented and include neurotoxicity, developmental delays, hypertension, impaired hearing acuity, impaired hemoglobin synthesis, and male reproductive impairment. Importantly, many of lead's health effects may occur without other overt signs of toxicity. Lead has particularly significant effects in children, and it appears that some of these effects, particularly changes in the levels of certain blood enzymes and in aspects of children's neurobehavioral development, may occur at blood lead levels so low as to be essentially without a threshold. Because of the difficulty in accounting for pre-existing body burdens of lead and the apparent lack of threshold, EPA determined that it was inappropriate to develop a RfD. The Centers for Disease Control (CDC) has identified a blood lead concentration of 10 micrograms per deciliter (µg/dL) as the level of concern above which significant health effects may occur (CDC 1991), and the concentration of lead in the blood is used as an index of the total dose of lead regardless of the route of exposure (EPA 1994). An acceptable risk is generally defined as a less than 5 percent probability of exceeding a blood lead concentration of 10 µg/dL (EPA 1998).

Using the ALM (EPA 2003c), acceptable lead concentrations in fish tissue that are unlikely to result in fetal blood lead concentrations greater than 10 µg/dL were calculated using the following equation:

$$PbF = \frac{\left(\left[PbB_f / R \times GSD^{1.645}\right] - PbB_o\right) \times AT}{BKSF \times \left(IR_F \times AF_F \times EF_F\right)}$$

Where:

PbB_a = Central tendency of adult blood lead level
PbB_o = Adult baseline blood lead level
PbB_f = Fetal blood lead level
R = Fetal/maternal blood lead ratio

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GSD = Geometric standard deviation PbB
BKSF = Biokinetic slope factor
PbF = Lead fish tissue concentration
IR_F = Consumption rate of fish
AF_F = Gastrointestinal absorption of lead from fish
EF_F = Exposure frequency for fish consumption
AT = Averaging time

The values used in this analysis are presented in Attachment F5. Because the lead models calculate a central tendency or geometric mean blood lead concentration, median values are typically used as inputs~~.–~~. The mean estimate of national per capita fish consumption of 7.5 g/day (EPA 2000b) was used as the consumption rate for recreational fishers, the median consumption rate of 39.2 g/day from the CRITFC study was used for tribal fishers. Using the equation presented above, the target lead concentrations in fish are 5.2 mg/kg for recreational fishers and 1 mg/kg for tribal fishers.

EPA's Integrated Exposure Uptake Biokinetic (IEUBK) model was used to calculate tissue lead concentrations unlikely to result in blood lead concentrations greater than 10 µg/dL in children. Because site-specific values for concentration of lead in soil, house dust, air and drinking water were not readily available, default values were used for those inputs. The ratio of child-to-adult consumption of 0.42 was applied to the median adult consumption rate of 7.5 g/day to obtain a childhood rate of 3.2 g/day for children of recreational fishers The corresponding lead concentrations in fish is 2.6 mg/kg~~.–~~. Assuming a consumption rate of 16.2 g/day for tribal children, representing the 65th percentile consumption rate from the CRITFC survey, the calculated lead concentration in fish is 0.5 mg/kg. Uncertainties associated with the evaluation of lead are discussed further in Section 6~~.–~~. ~~A great o a predicted probability of no more than 5 percent greater than the 10 µg/dl level (EPA 1998).~~

~~For receptors where only adult exposure was evaluated, the adult cancer risk was used for the mother cancer risk. For noncancer hazards, the adult hazard quotient was used for the mother hazard quotient.When assessing cancer risks, an~~

~~The IRAFs used to assess risks were from DEQ guidance (2010). Specifically, IRAFs of 1 were was used for PCB, PCB TEQ, and dioxin TEQ, cancer risks. An IRAF of 0.007 was used for DDX DDxcancer risks. IRAFs of 2 were used for PCB TEQ, dioxin TEQ, and DDX DDx noncancer hazards. An IRAF of 25 was used for PCB noncancer hazards.~~

~~7.0 The risks to infants through consumption of human milk are presented in the risk characterization results below.~~

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~~5.11.5~~5.1.5 Cumulative Risk Estimates for Contaminants Analyzed by More Than One Method

~~Noncancer HQs and cancer risks were calculated for all individual contaminants for which EPCs were available, as described above.~~ In some ~~cases~~instance~~,~~s specific contaminants were analyzed by ~~different~~ more than one method~~s~~, ~~so~~ and thus more than one ~~there were multiple~~ EPCs calculated for that contaminant~~.~~. C~~In calculating the c~~umulative risks~~, only the risk associated with the EPC~~are presented using the EPC from only one method ~~for one method was included in the sum~~ to avoid double-counting the risks from a given contaminant~~.~~.

When assessing risks associated with sediment exposures, ~~For example, total PCBs were analyzed both as congeners and as Aroclors. In sediment, the~~ Aroclor data was used because the data set was larger than for congeners. ~~, so the risk from total PCBs as Aroclors was included in the cumulative risk estimate for sediment. For~~However ~~tissue~~, because the congener analysis ~~provides~~ provided ~~better~~ lower detection limits, it was preferentially used when available for assessing risks associated with consumption of fish and shellfish. ~~. Therefore, the risk from total PCBs as congeners was included in the cumulative risk estimate for tissue, if congener data were available. If no congener data were not available for tissue, the risk from total PCBs as Aroclors was used in when estimating the cumulative risk for tissuefrom consumption of fish.~~.

Where ~~metals~~metals were analyzed as both total and dissolved fractions ~~In~~ in surface water and ~~most of the~~ groundwater seep samples, the EPCs ~~for~~based on total metals were used in the cumulative risk estimates ~~as a conservative approach, b metals were analyzed as both total and dissolved. Because total concentrations are were typically highergreater than the results for dissolved concentrations~~because unfiltered data is generally more representative of typical human exposure~~, the EPCs for total metals were included in the cumulative risk estimates as a conservative approach~~.

~~8.0 The individual risks from the EPCs for all of the analytical methods are presented in the risk characterization result tables (Tables 5-2 through 5-98). The tables also indicate which results were included in the cumulative risks when multiple EPCs were available for a given chemical.~~

~~5.12~~5.2 RISK CHARACTERIZATION RESULTS

This section presents ~~the results~~a summary of the risk characterization results ~~for each of~~ the scenarios described in Section 3~~.~~. ~~Consistent with~~ EPA policy (EPA 1991a)~~,~~ states that CERCLA actions are generally warranted when where the baseline risk assessment indicates that a cumulative site risk to an individual using RME assumptions for either current or future land use is greater than the 1 x 10^{-4} lifetime excess cancer risk end of the cancer risk range of 1 x 10^{-4} to 1 x x 10^{-6}, or the HI is greater than 1. Accordingly, risk and hazard estimates are generally presented in terms of whether they are greater than the upper end of the cancer risk range of

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1 x 10^{-4} or the HI is greater than 1. Uncertainties associated with the assumptions in each exposure scenario are discussed in detail in Section 6~~.~~. Risks from exposures to PBDEs in in-water sediment and tissue were assessed separately, and are presented in Attachment F3~~.~~. ~~If actual exposures for each scenario were less than the exposures assumed in the risk calculations, the estimated risks would also decrease correspondingly.~~

5.2.1 Dockside Workers

Risks ~~for~~to dockside workers were estimated separately for each of the eight beaches designated as a potential dockside worker use areas, ~~which are~~ shown in Map 2-1. ~~The results of the risk evaluation for dockside worker exposure to beach sediment are presented in Tables 5-2 through 5-3.~~

~~The dockside worker RME scenario for beach sediment results in exceedances of a~~The estimated CT and RME cancer risks are less than ~~is cumulative cancer risk level of 1 x 10^{-6} at beaches 9~~1 x 10^{-4}~~5~~ ~~at beach 06B025 (9 x 10^{-5} riskadjacent to NW Natural at approximately RM 6.5W), and 2 x 10^{-6} andat beach B004 (2 x 10^{-6} riskadjacent to Oregon Steel Mills at RM 2E). The primary contributors to the estimated cancer riskscPAHs in beach sediment, including In addition to benzo(a)pyrene, other chemicals contributing to a calculated individual cancer risk greater than 1 x 10^{-6} for at least one exposure area include: benzo(a)anthracene, benzo(b)flouranthene, dibenzo(a,h)anthracene, and indeno(1,2,3-cd)pyrene are the primary contributors to the estimated risks.. The estimated RME cancer risk was less than 1 x 10^{-6}~~ at all ~~other locations~~beach areas~~. There are no exposure areas that result in an exceedance of 1 x 10^{-4} cancer risk for the dockside worker RME scenario. The maximum cumulative cancer risk for an individual exposure area occurs at 06B025 and is primarily due to incidental ingestion of beach sediment containing benzo(a)pyrene. In addition to benzo(a)pyrene, other chemicals contributing to a calculated individual cancer risk greater than 1 x 10^{-6} for at least one exposure area include: benzo(a)anthracene, benzo(b)flouranthene, dibenzo(a,h)anthracene, and indeno(1,2,3-cd)pyrene. The~~, and the HIs ~~for the dockside worker RME scenario do not exceed~~is less than 1 for adults and ~~breastfed~~ infants ~~for all beaches evaluated.~~.

~~The dockside workerestimated cancer risk for CT exposures iis less thans 61 x 10^{-64} scenario at beach 06B025. cPAHs in beach sediment are the primary contributors to the estimated risk. for beach sediment results in one exceedance of 1 x 10^{-6} cumulative cancer risk (at beach 06B025, 6 x 10^{-6} risk), which is primarily due to the incidental ingestion of sediment containing benzo(a)pyrene. There are no exposure areas that result in an exceedance of 1 x 10^{-4} cancer risk for the dockside worker CT beach sediment scenario. The dockside worker CT scenario results in no exceedances of aThe HI ofwas less than 1at all beaches, and the HI is less than 1 .. Figures 5-1 shows risks to the dockside worker from exposure to beach sediment per beach, and shows the relative contribution of individual chemicals to total risk.~~

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5.2.2 In-Water Workers

As discussed in Section 3.2.1.2, in-water workers are described as typically working around in-water structures such as docks, and primarily exposed to in-water sediments~~.~~. In-water sediment exposure by in-water workers was evaluated in half-mile increments along each side of the river. ~~The results of the risk evaluation for in-water worker exposure to in-water sediment are presented in Tables 5-21 through 5-22.~~

~~The in-water worker RME scenario for in-water sediment results in cumulative cancer risk greater than~~The estimated CT and RME cancer risks ~~was~~are ~~greater~~less than 1 x 10^{-46} at ~~three~~all ~~RM~~ RM segments, ~~4.5E, 6W, and 7W. The estimated cancer risk at 2 x 10^{-6} at RM 4.5E and 9 x 10^{-6} is at RM 6W 2 x 10^{-6}, and cPAHs in river sediment are the primary contributors the risk estimate. The estimated RME cancer risk is 2 x 10^{-5} at RM 7W, where dioxins and furans in river sediment are the primary contributors to the estimated risks. There are no exceedances of 1 x 10^{-4} cancer risk for the in-water worker RME scenario. The maximum cumulative cancer risk for an individual exposure area occurs at RM 7W (2 x 10^{-5}) and is primarily due to incidental ingestion of sediment containing dioxins/furans. The only other individual contaminant resulting in a cancer risk greater than 1 x 10^{-6} within the Study Area is benzo(a)pyrene. T~~and the RME HIs for ~~in-water~~ adults ~~worker RME scenario do not exceed~~are less than 1 at any location.~~,~~ ~~t~~The HI for infants is 2 at ~~RM~~ RM 7W, and dioxin and furans are the primary contributors to the estimate.~~.~~

~~The in-water worker RME scenarios do not result in an exceedance of 1 x 10^{-6} cumulative cancer risk or an HI greater than 1 for exposure to in-water sediment from river segments assessed outside of the Study Area.~~

~~The in-water worker The estimated cancer risks for the CT scenario for in-water sediment results in no exceedances of are less than 1 x 10^{-46} cancer risk and no exceedances of an at all locations, and the HI ofis less than 1.~~ These results ~~of the risk evaluation for in-water workers and their children exposure to in-water sediment~~ are presented in Tables 5-21~~-~~, ~~and~~ 5-22, 5-34 and 5-35.~~.~~

5.2.3 Transients

Risks ~~for~~to transients were estimated separately for each beach designated as a potential transient use area, as well as the use of surface water as a source of drinking water and for bathing~~.~~. Beaches where sediment exposure was evaluated are shown ~~i~~on Map~~-~~ 2-~~-~~1. Year-round exposure to surface water for four individual transect stations, Willamette Cove, Multnomah Channel, and for the four transects grouped together to represent Study Area-wide exposure are shown on Map 2-3. The CT and ~~The transient~~ RME ~~scenario~~risks estimates for beach sediment ~~results in no exceedances of~~ ~~was~~are less than 1 x 10^{-64} ~~cancer risk and no exceedances of a~~for all locations, and the HI is ~~of~~less than 1. The ~~transient CT scenario for beach sediment results in no exceedances of 1 x 10^{-6} cancer risk and no exceedances of a HI of 1. The~~

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~~results of the risk evaluation for transient exposure to beach sediment~~results of the RME and CT evaluations for exposure to beach sediments are~~ are~~ presented in Tables 5--4 ~~through~~and 5--5, respectively.

Estimated CT and RME cancer risks associated with surface water exposures are less than 1 x 10^{-64} at all individual and transect locations, and the HI is less than 1. The results of the RME and CT evaluations are ~~Risks to transients from surface water were evaluated for drinking water and bathing scenarios. The risks were evaluated for year-round exposure to surface water for four individual transect stations, for the four transects grouped together (to represent Study Area-wide exposure), and for Willamette Cove. In addition to these exposure areas within the Study Area, risk was evaluated for exposure to surface water for a transect in Multnomah Channel, which is outside of the Study Area. The results of the risk evaluation for transient exposure to surface water are~~ presented in Tables 5-46 ~~through~~and 5-47, respectively. ~~With the exception of the surface water sample collected from Willamette Cove, data used to evaluate exposure to beach sediments and surface water exposures are not co-located. The cumulative risk associated with concurrent exposure to beach sediments and surface water at Willamette Cove is approximatelyis less than 1 x 10^-46.~~

~~The transient RME and CT scenarios for surface water result in no exceedances of 1 x 10^-6 cancer risk and no exceedances of an HI of 1 inside or outside of the Study Area.~~

~~Risks to transients from the~~As noted in Section 3.3.4, exposure to surface water by transients was also evaluated at the groundwater seep at Outfall 22B~~—~~. All risk and hazard estimates ~~were~~are less than 1 x 10^{-64} and 1, respectively, and t ~~evaluated for direct contact scenarios. There were multiple uncertainties associated with the exposure parameters for the direct exposure to groundwater seeps scenario. To evaluate the risks from exposure to the groundwater seep without stormwater influence, outfall data from stormwater sampling events was excluded from the dataset.~~ The results ~~of the risk evaluation for transient exposure to the groundwater seep~~ are presented in Tables- 5--64 ~~through~~and 5--65.

5.2.4 Divers

C~~Risks were evaluated for c~~ommercial divers were evaluated for exposure to surface water and in-water sediment, and assuming the diver was wearing either a wet ~~suit~~ or a dry suit~~,~~. ~~a~~As described in Section 3.4.2, in-water sediment exposure by divers is evaluated in half-mile exposure areas for each side of the river, and on a Study Area wide basis. Risks associated with exposure to surface water were evaluated for four individual transect stations, and at single-point sampling stations grouped together in one-half mile increments per side of river~~. The results of the risk evaluation for commercial wet suit diver exposure to in-water sediment are presented in Tables 5-31 through 5-32. The results of the risk evaluation for a commercial dry suit diver exposure to in-water sediment are presented in Table 5-33~~.

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5.2.4.1 Diver in Wet Suit

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The ~~commercial diver in a wet suit~~estimated CT and RME ~~and CT~~ cancer risk associated with exposure to in-water sediments is less than ~~scenario for in-water sediment results in exceedances of~~ 1 x 10^{-64} ~~cumulative cancer risk in~~at ~~10~~all ~~of 40 ½~~half-~~-~~mile river ~~mile~~ segments ~~within the Study Area~~ and for Study Area-wide exposure, and the HI is also less than 1 for adults. The HI for infants is 2 at ~~RM~~ RM 8.5W for the RME evaluation, and PCBs are the primary contributor to the hazard estimate. The ~~results of the~~ RME and CT estimates for adults are presented in Tables 5-31 and 5-32, respectively~~.~~. RME and CT risk and hazard estimates for infant exposures are presented in Tables 5-42 and 5-43, respectively.

The estimated CT and RME ~~and CT~~ cancer risk associated with exposure to surface water is less than 1 x 10^{-4} for all half-mile river segments, and the HI is less than 1~~.~~. ~~Infant exposure to contaminants in surface water via breastfeeding was not evaluated.~~ These results are presented in Tables 5-54 and 5-55, respectively, for the RME and CT evaluations. Indirect exposure to contaminants in surface water by infants via breastfeeding was not evaluated~~.~~. ~~(see Table 5-31). There are no exceedances of 1 x 10^{-4} cancer risk for this scenario. The maximum cumulative cancer risk (3 x 10^{-5}) occurs at RM 6W and RM 7W. At RM 6W, the risk is primarily due to dermal adsorption of sediment containing benzo(a)pyrene. At RM 7W, the risk is primarily due to dermal absorption of sediment containing dioxins and furans. In addition to these two chemicals, the following individual analytes also result in a cancer risk greater than 1 x 10^{-6} in at least one exposure area: PCBs, benzo(b)fluoranthene, dibenzo(a,h)anthracene, benzo(a)anthracene, and indeno(1,2,3-cd)pyrene. The commercial diver in a wet suit RME scenario for in-water sediment results in no HIs greater than 1.~~

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~~There are no exposure areas outside of the Study Area that result in risks above 1 x 10^{-6} or HIs greater than 1 for this scenario.~~

~~The commercial diver in a wet suit CT scenario for in-water sediment results in no exceedances of 1 x 10^{-6} cumulative cancer risk and no exceedances of an HI of 1 for exposure areas assessed inside and outside of the Study Area (see Table 5-32).~~

5.2.4.2 Diver in Dry Suit

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The estimated RME cancer risk is less than 1 x 10^{-4} at all half-mile river segments and for Study Area-wide exposure, and the HI is also less than 1 for adults and infants~~.~~. The results of the adult RME risk and hazard estimates are presented in Table 5-33, ~~The commercial diver in a dry suit RME scenario for in-water sediment results in exceedances of 1 x 10^{-6} cumulative cancer risk in two of 40 river mile segments within the Study Area (see Table 5-33). The maximum cumulative cancer risks occur at RM 7W (1 x 10^{-5}) and RM 6W (6 x 10^{-6}). At RM 7W, risk is primarily due to incidental ingestion of sediment containing dioxins/furans. At RM 6W, risk is~~

~~primarily due to dermal contact with sediment containing benzo(a)pyrene. No other analytes result in a cancer risk greater than 1 x 10^{-6} for this scenario. The commercial diver in a dry suit RME scenario for in-water sediment results in no HIs greater than 1. There are no river mile segments outside of the Study Area that result in risk above 1 x 10^{-6} or an HI greater than 1. A~~a CT ~~scenario~~evaluation was not ~~evaluated~~done for a commercial diver in a dry suit~~, per direction from EPA~~.

The estimated RME cancer ~~and CT cancer~~ risk associated with exposure to surface water is less than 1 x 10^{-4} for all half-mile river segments, and the HI is less than 1~~—~~. ~~Infant exposure to contaminants in surface water via breastfeeding was not evaluated.~~ These results are presented in Tables 5-56. Indirect exposure to contaminants in surface water by infants via breastfeeding was not evaluated~~—~~. ~~Risks to commercial divers from surface water were evaluated for year-round exposure to four individual transect stations, and to single-point sampling stations within the Study Area grouped together on a ½-river mile basis, per side of river (E, W). In addition to these exposure areas within the Study Area, risk was evaluated for exposure to surface water for a transect in Multnomah Channel, which is outside of the Study Area. Risks were evaluated for commercial divers in wet suits and in dry suits. The results of the risk evaluation for commercial divers in wet suits exposure to surface water are presented in Tables 5-54 through 5-55. The results of the risk evaluation for commercial divers in dry suits are presented in Table 5-56.~~

~~**Diver in Wet Suit**~~

~~The commercial diver in a wet suit RME scenario for surface water results in exceedances of 1 x 10^{-6} cumulative cancer risk in one exposure area (RM 6W). There are no exceedances of 1 x 10^{-4} cancer risk for the commercial diver in a wet suit RME scenario. The maximum cumulative cancer risk occurs at RM 6W (1 x 10^{-5}) and is primarily due to dermal contact with surface water containing benzo(a)pyrene. There are no other analytes resulting in a cancer risk greater than 1 x 10^{-6}. The commercial diver in a wet suit RME scenario for surface water resulted in no HIs greater than 1. There are no exceedances of 1 x 10^{-6} risk or an HI of 1 for surface water exposure to river segments assessed outside of the Study Area.~~

~~The commercial diver in a wet suit CT scenario for surface water results in no exceedances of 1 x 10^{-6} cumulative cancer risk and no exceedances of an HI of 1 for exposure inside or outside of the Study Area.~~

~~**Diver in Dry Suit**~~

~~The commercial diver in a dry suit RME scenario for surface water results in exceedances of 1 x 10^{-6} cumulative cancer risk in one exposure area (RM 6W). This exposure area is the location of the maximum cumulative cancer risk (2 x 10^{-6}) and is primarily due to dermal contact with surface water containing benzo(a)pyrene. There are no individual analytes resulting in a cancer risk greater than 1 x 10^{-6}. The~~

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~~commercial diver in a dry suit RME scenario for surface water resulted in no HIs greater than 1. There are no exceedances of 1 x 10^{-6} risk or an HI of 1 for surface water exposure to river segments assessed outside of the Study Area.~~

~~The commercial diver in a dry suit was not evaluated for CT exposure, as directed by EPA.~~

5.2.5 Recreational Beach Users

~~**Recreational Beach Users**~~

Risks ~~for~~associated with exposure to beach sediment were evaluated~~ the recreational beach users were estimated~~ separately for each beach designated as a potential recreational use area,~~ which are~~ shown ~~in~~on Map- 2--1. Exposure to surface water was evaluated ~~at~~using data collected from three transect locations and three single-point locations (Cathedral Park, Willamette Cove, and Swan Island Lagoon) shown on Map 2-3.

The estimated CT and RME ~~and CT~~ cancer risks associated with exposure to beach sediments ~~is~~are less than 1 x 10^{-4} at all recreational beach areas, and the HI is also less than 1. ~~Cancer risks and noncancer hazards were evaluated for both children (ages 0-6 years) and adults (ages 7-30 years) and child recreational beach users. In addition, as described in carcinogenic risks were calculated for a combined child and adult for a combined 30 year scenario.~~ These results ~~of the risk evaluation for recreational beach user exposure to beach sediment~~ are presented in Tables- 5--6 through 5--11. Indirect exposure to contaminants in beach sediment to infants via breastfeeding was not evaluated~~—~~.

~~**Adult Recreational Beach Users**~~

~~The adult recreational beach user RME scenario for beach sediment results in cumulative cancer risk exceedances of 1 x 10^{-6} at the following beaches: 04B024 (risk is 3 x 10^{-6}), 06B030 (risk is 4 x 10^{-6}), B003 (risk is 3 x 10^{-6}), and B005 (risk is 2 x 10^{-6}). There are no exceedances of 1 x 10^{-4} cancer risk for the adult recreational beach user RME scenario. The maximum cumulative cancer risk from RME occurs at Beach 06B030 and is primarily due to incidental ingestion of beach sediment containing arsenic. The adult recreational beach user RME scenario for beach sediment resulted in no HIs greater than 1. Figures 5-2 and 5-3 show the relative risk contribution of individual COPCs for each beach, as well as total risk by river mile for adult recreational beach user exposure to beach sediment.~~

~~Arsenic is a naturally occurring metal. The concentration for arsenic in soil recognized by DEQ to represent background levels in Oregon is 7 milligrams per kilogram (mg/kg) (DEQ 2007). At this background concentration, the calculated risk from arsenic would exceed 1 x 10^{-6} for the adult recreational beach user RME scenario. When a background concentration of 7 mg/kg is subtracted from detected concentrations of arsenic in beach sediment, resulting cumulative risks for the adult recreational beach user RME scenario exceed 10^{-6} at beaches 04B024 and B003. Beaches with risk exceedances of 1 x 10^{-6}~~

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~~excluding risks from background arsenic are shown for all exposure scenarios for beach sediment in Maps 5-2-1 and 5-2-2. In addition to risks from exposure to arsenic in beach sediment, risks from exposure to total cPAHs in beach sediment exceed 1 x 10^{-6} at two beach locations: 04B024 (2 x 10^{-6}) and B003 (2 x 10^{-6}) At each of these beaches, benzo(a)pyrene is the cPAH with the highest contribution to total risks from cPAHs.~~

~~The adult recreational beach user CT scenario for beach sediment results in no exceedances of 1 x 10^{-6} cumulative cancer risk and no exceedances of an HI of 1.~~

~~Child Recreational Beach Users~~

~~The child recreational beach user RME scenario for beach sediment results in cumulative risk exceedances of 1 x 10^{-6} at all 15 of the exposure areas. There are no exceedances of 1 x 10^{-4} cancer risk for the child recreational beach user RME scenario. The maximum cumulative cancer risk from RME occurs at beaches B003, and 04B024 (4 x 10^{-5}) and is primarily due to dermal absorption of soil containing arsenic and benzo(a)pyrene. The child recreational beach user RME scenario resulted in no HIs greater than 1.~~

~~The cumulative risk exceedances are due in part to arsenic, which is naturally occurring. At the DEQ background soil concentration of 7 mg/kg, the calculated risk from arsenic would exceed 1 x 10^{-6} for the child recreational beach user RME scenario. When a background arsenic concentration of 7 mg/kg is subtracted from detected arsenic concentrations in beach sediment from potential human use areas, resulting cumulative risks for the child recreational beach user RME scenario exceed 1 x 10^{-6} at five beaches, as shown in Map 5-2-1. These exceedances are due to exposure to arsenic at one beach, and exposure to benzo(a) pyrene or total cPAHs at the other four. Cancer risks above 1 x 10^{-6} from exposures to cPAHs in beach sediment range from 2 x 10^{-8} to 4 x 10^{-5}, due primarily to contributions from benzo(a)pyrene. Figures 5–4 and 5–5 show the relative risk contribution of individual COPCs forat each beach, as well as total risk by river mile for child recreational beach user exposure to beach sediment.~~

~~The child recreational beach user CT scenario for beach sediment results in an exceedance of 1 x 10^{-6} cumulative cancer risk at two beaches (risk of 2 x 10^{-6} at 04B024 and B003). There are no exceedances of an HI of 1.~~

~~Combined Child/Adult Recreational Beach Users~~

~~Cancer risks were calculated for the combined child and adult recreational beach users to incorporate early life exposures in accordance with EPA (2005b) and DEQ (2010) guidance. Cumulative risks per exposure area for RME scenarios ranged from 2 x 10^{-6} to 5 x 10^{-5}. For the CT scenarios, risks ranged from 2 x 10^{-7} to 2 x 10^{-6}. The highest risk was at Beach 04B024, primarily due to exposures to benzo(a)pyrene in beach sediment.~~

~~Risks to recreational beach users fromassociated with exposure to surface water were evaluated for swimming scenarios, using data from summer monthsassociated with~~

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~~recreational activities . Risks were evaluated for exposure to surface water forusing data from the three transects grouped together (to represent Study Area-wide exposure) and for exposure to surface water for three individual quiescent areas during summer months. Risks for both adults and children were evaluated, as well as cancer risks to a combined child and adult receptor, in order to incorporate early-life exposures.~~ The results of the risk evaluation for exposure to surface water by ~~adult~~ recreational beach user ~~exposure to surface water~~ are presented in Tables 5--48 through 5--~~49~~53. The estimated CT and RME ~~and CT~~ cancer risks associated with exposure to surface water are less than 1 x 10^{-4} at all recreational beach areas, and the HI is also less than~~The results of the risk evaluation for child recreational beach user exposure to surface water are presented~~ 1. These results are presented in Tables 5--50 through ~~5-51. The results of the combined child and adult receptor are presented in Tables 5-52 through~~ 5-53.

~~The adult, child, and combined recreational beach user RME and CT scenarios for surface water result in no exceedances of 1 x 10^{-6} cancer risk and no exceedances of an HI of 1.~~

5.2.6 Recreational/Subsistence Fishers

Recreational and subsistence fishers were evaluated ~~for~~assuming ~~exposures associated with~~ direct exposure to contaminants in sediment and via consumption of fish and shellfish. As discussed in Section 3.2.1.6, ~~Risks~~exposures associated with beach sediment ~~exposures~~ were assessed at individual beaches designated as potential transient or recreational use areas, ~~risks associated with~~ in-water sediment exposures were evaluated on a one-half river mile basis per side of the river and as an averaged, Study Area-wide evaluation. Sediment exposures were further assessed as CT and RME evaluations ~~by~~and ~~based on the fishing frequency as~~ assuming either a low-~~frequency (RME and CT)~~ or a high-frequency rate of fishing~~y (CT and RME). Unlike other exposures, such as contact with contaminants in soil, The results of the risk evaluation for high-frequency fisher exposure to beach sediment are presented in Tables 5-14 through 5-15~~

5.2.6.1 ~~Beach~~ Sediment-Direct Contact

~~.~~

The estimated CT and RME cancer risks associated with low-frequency fishing exposures to either beach or in-water sediments are less than 1 x 10^{-4} at all areas evaluated. Noncancer hazards associated with ~~combined child and~~ adult exposures are less than 1 at all locations evaluated, the noncancer hazard associated with indirect exposures to infants via breastfeeding is greater than 1 at two locations: ~~RM~~ RM 7W (2), where dioxin/furan TEQ concentrations are the primary contributor, and ~~RM~~ RM 8.5W (2), where PCBs are the primary contributor, with a HQ of 1. ~~Cancer risks and noncancer hazards associated with exposure to beach sediments~~ These results are

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presented in Tables 5-16 and 5-17 for beach sediment exposures, and Tables 5-29 and 5-30 for in-water sediment exposures.~~,~~

The estimated CT and RME cancer risks associated with high-frequency fishing exposures to either beach or in-water sediments are less than 1 x 10^{-4} at all areas evaluated. Noncancer hazards associated with ~~combined child and~~ adult exposures ~~is~~are greater than 1 at ~~RM~~ RM 7W (2), with dioxin/furan TEQ concentrations as the primary contributor the noncancer hazard. -The noncancer hazard associated with indirect exposures to infants via breastfeeding is also greater than 1 at ~~RM~~ RM 7W (3), where dioxin/furan TEQ concentrations are the primary contributor, and ~~RM~~ RM 8.5W (2), where PCBs are the primary contributor with a HQ of 2. These results ~~of the risk evaluation for high-frequency fisher exposure to beach sediment~~ are presented in Tables 5-14 ~~through~~and 5-15 for beach sediment exposures, and Tables 5-26 through 5-28 for in-water sediment exposures.

5.2.6.2 Consumption of Smallmouth Bass

Consumption of both whole body and fillet-only smallmouth bass was evaluated on a river mile basis to account for their relatively small home range. An additional analysis averaging consumption over the entire Study Area was also conducted. The estimated CT and RME ~~RME~~ cancer risks associated with combined child and adult consumption of whole body smallmouth bass ~~consumption associated with~~are greater than 1 x 10^{-4} ~~at~~for all ~~areas~~river miles evaluated, and ~~-~~RME cancer risk estimates are greater than 1 x 10^{-3} for each river mile except ~~RM~~ RM 5, where the estimated risk is 9 x 10^{-4} for the recreational fisher. CT cancer risk estimates are greater than 1 x 10^{-3} at RM 7, RM 11, and at Swan Island Lagoon. Study Area-wide RME risks for recreational and subsistence fishers are 7 x 10^{-3} and 4 x 10^{-3}, the CT estimate for recreational fishers is 9 x 10^{-4}. Values for river miles having the highest estimated RME risks are as follows (for recreational and subsistence fishers, respectively): RM 7 (5 x 10^{-3} and 1 x 10^{-2}), Swan Island Lagoon (5 x 10^{-3} and 1 x 10^{-2}), and RM- 11 (8 x 10^{-3} and 2 x 10^{-2}). Dioxins/furans, PCBs and DDx are the primary contributors to the overall risk at RM 7; PCBs, and to a lesser degree dioxins/furans, are the primary contributors in Swan Island Lagoon and at RM 11.

RME risk estimates for fillet-only consumption ~~range upwards from 9 x 10^{-5} and~~are all greater than ~~2~~1 x 10^{-4}, the CT estimate is greater than 1 x 10^{-4} at RM 7 and RM 11 ~~respectively, at RM 5~~. Study Area-wide RME risks for recreational and subsistence fishers are 2 x 10^{-3} and 9 x 10^{-4}, the CT estimate for recreational fishers is 2 x 10^{-4}. River miles having the highest estimated risks are (for recreational and subsistence fishers, respectively): RM- 7 (8 x 10^{-4} and 2 x 10^{-3}) and RM- 11 (1 x 10^{-3} and 3 x 10^{-3}), fillet-only data ~~are not available~~were not collected ~~for~~in Swan Island Lagoon.~~ Study Area-wide RME risks for recreational and subsistence fishers are 3 x 10^{-3} and 6 x 10^{-3}.~~ Dioxins/furans and PCBs are the primary contributors to the overall risk as ~~RM~~ RM 7, PCBs, and to a lesser degree dioxins/furans, are the primary contributors in Swan Island Lagoon and at RM- 11. These results are presented in Table 5-114.

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RME~~ for .~~ n~~N~~oncancer hazards associated with childhood ~~combined child and adult~~ consumption of whole body smallmouth bass are greater than ~~50~~1~~ and 100 at RM 5, respectively, for recreational and subsistence fishing~~ at all river miles evaluated. A~~The pattern of a~~reas with the ~~greatest~~highest estimated hazard displays a pattern similar to those with highest cancer risks. -Values for river miles having the highest estimated hazard are as follows (for recreational and subsistence fishers, respectively): RM- ~~2~~7 (300 and 600), Swan Island Lagoon (500 and 1,000), and RM 11 (700 and 1,000). The highest values for the CT noncancer hazard estimates for recreational fishers are 70 (RM 7), 200 (RM 11), and 100 (Swan Island Lagoon). Study Area-wide RME hazards for recreational and subsistence fishers are 200 and 500, respectively, the CT estimate for recreational fishers is 60. Dioxins/furans and PCBs are the primary contributors at RM 7, while PCBs are predominantly the contributor in Swan Island Lagoon and at RM 11.

-RME hazard estimates for fillet-only consumption are also greater than 1 at all river miles. ~~The lowest hazard estimate is 9, at RM 5.~~ Values for river miles having the highest estimated RME hazard for fillet-only consumption are as follows (for recreational and subsistence fishers, respectively): ~~RM 4 (30 and 60),~~ RM- 7 (50 and 90), and RM- 11 (100 and 300); fillet-only data were not collected in Swan Island Lagoon. Study Area-wide RME hazards for recreational and subsistence fishers are 70 and 100, respectively, the CT estimate for recreational fishers is 20. PCBs and dioxin/furans are the primary contributors to the hazard estimates at RM 7 while PCBs are the primary contributor to the hazard estimate at RM 11. ~~PCBs and dioxin/furans are the primary contributors to the hazard estimates.~~ These results are presented in Table 5-94.

~~N~~RME and CT noncancer hazard associated with indirect exposure to infants via breastfeeding was also assessed. Values for river miles having the highest estimated RME hazard due to consumption of whole body smallmouth bass are as follows (for infant children of recreational and subsistence fishers, respectively): ~~RM 2 (400 and 2,000),~~ RM- 7 (~~6~~3,000 and ~~3~~5,000), Swan Island Lagoon (~~1,000 and~~ 6,000 and 10,000), and RM- 11 (~~2,000 and~~ 8,000 and 20,000). The associated CT estimates for recreation fishers are 600 at RM 7, 1,000 at Swan Island Lagoon, and 2,000 at RM 11. The ~~comparable~~ RME hazard estimates associated with fillet-only consumption are: ~~RM 4 300 and 600),~~ RM- 7 (300 and 600), and RM- 11 (2,000 and 4,000), fillet-only data were not collected in Swan Island Lagoon. The comparable CT estimates for recreational fishers are 70 at RM 7, and 500 at RM 11. PCBs are the primary contributors to the estimated noncancer hazard estimates. These results are presented in Table 5-119.~~exposures are less than 1 at all locations evaluated, the noncancer hazard associated with indirect exposures to infants via breastfeeding is greater than 1 at two locations: RM 7W (2), where dioxin/furan TEQ concentrations are the primary contributor, and RM 8.5W (2), where PCBs are the primary contributor, with a HQ of 1. Cancer risks and noncancer hazards associated with exposure to beach sediments are presented in Tables 5-16 and 5-17~~

5.2.6.3 Consumption of Common Carp

The estimated ~~CT and~~ RME cancer risks associated with combined child and adult consumption of whole body ~~smallmouth bass~~common carp are greater than 1 x 10^{-4} ~~for all river miles at~~in each fishing zone evaluated, and RME cancer risk estimates are greater than 1 x 10^{-34}. ~~for each river mile except RM 5, where the estimated risk is 9 x 10^{-4} for the recreational fisher.~~ Values for ~~river miles~~fishing zones having the highest estimated risks are as follows (RME estimates for recreational and subsistence fishers, respectively): ~~RM~~FZ- ~~7~~3-6 (~~5~~1 x 10^{-32} and ~~1~~2 x 10^{-2}), ~~Swan Island Lagoon~~FZ- 4-8 (~~5~~3 x 10^{-32} and ~~1~~7 x 10^{-2}, and ~~RM~~FZ 8-12 ~~11~~ (~~8~~2 x 10^{-3} and 5 x 10^{-3}). The ~~associated~~ Study Area-wide risk estimates are 4 x 10^{-2} and 2 x 10^{-2}. CT estimates for recreational fishers are greater than 1 x 10^{-4} ~~at~~in all fishing zones, and is 5 x 10^{-3} when evaluated Study Area-wide. PCBs, dioxins/furans, and DDx are the primary contributors in FZ 4-8 and PCBs are the primary contributors in FZ 3-6 (dioxins/furans were not analyzed in this FZ).

The ~~comparable~~RME risk estimates for fillet-only consumption (for recreational and subsistence fishers, respectively) are:~~are~~ FZ- 3-6 (1 x 10^{-3} and 2 x 10^{-3}), FZ- 4-8 (2 x 10^{-2} and 4 x 10^{-2}, and FZ 8-12 (1 x 10^{-3} and 2 x 10^{-3}). The Study Area-wide RME risk estimates are 4 x 10^{-2} and 2 x 10^{-2}. The CT estimate for recreational fishers is 1 x 10^{-4} ~~at~~in FZ 0-4, all other CT estimates are greater than 1 x 10^{-4}. ~~The associated Study Area-wide risk estimates assuming fillet-only consumption are 4 x 10^{-2} and 2 x 10^{-2}.~~ These results are presented in Table 5-115.

RME noncancer hazards associated with childhood consumption of whole body common carp are greater than 1 ~~at~~in each fishing zone evaluated. Values for fishing zones having the highest estimated ~~risks~~hazard are as follows (RME estimates for recreational and subsistence fishers, respectively):- FZ 3-6 (900 and 2,000) and FZ 4-8 (3,000 and 5,000). The Study Area-wide estimates are 2,000 and 4,000. The associated CT estimates for recreational fishers is 200 at FZ 3-6, 600 ~~at~~in FZ 4-8, and 500 Study Area-wide. The comparable hazard estimates for fillet-only consumption are: FZ 3-6 (200 and 100), FZ 4-8 (4,000 and 2,000), and 500 Study Area-wide. CT estimates for recreational fishers are 30 ~~at~~in FZ 3-6-, 500 ~~at~~in FZ 4-8, and 500 Study Area-wide.~~FZ 3-6 (2,000 and 900), FZ 4-8 (5,000 and 3,000, and FZ 8-12 (400 and 200). The comparable hazard estimates for fillet-only consumption are: FZ 3-6 (200 and 100), FZ 4-8 (4,000 and 2,000, and FZ 8-12 (200 and 90).~~ PCBs are the primary contributors to the hazard estimates. These results are presented in Table 5-98

RME noncancer hazards associated with indirect exposure to infants via breastfeeding are greater than 100 ~~at~~in each fishing zone evaluated. Values for fishing zones having the highest estimated ~~risks~~hazard are as follows (infant children of recreational and subsistence fishers, respectively): ~~FZ~~ FZ 3-6 (~~2~~10,000 and ~~1~~20,000)~~,~~ and ~~FZ~~ FZ 4-8 (~~6~~30,000 and ~~3~~60,000)~~, and FZ 8-12 (3,000 and 1,000);~~ ~~.~~Study Area-wide estimates are 30,000 and 50,000, respectively. The comparable CT estimates for infants of recreational fishers are 3,000 ~~at~~in FZ 3-6, 8,000 ~~at~~in FZ 4-8, and 6,000 Study Area-wide.

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~~The comparable~~ RME ~~comparable~~ hazard estimates associated with fillet-only consumption are (for infants of recreational and subsistence fishers, respectively): ~~FZ~~ FZ 3-6 (~~3~~1,000 and ~~1~~3,000)~~,~~; ~~FZ~~ FZ 4-8 (~~5~~30,000 and ~~3~~50,000); the Study Area-wide estimates are 30,000 and 50,000~~, and FZ 8-12 (2,000 and 1,000)~~. ~~The~~ CT estimates for infants of recreational fishers are 400 ~~at~~in FZ 3-6, 6,000 at FZ 4--8, and 6,000 Study Area-wide. PCBs are the primary contributors to the hazard estimates. ~~The comparable hazard estimates Study Area-wide are 30,000 and 50,000, respectively.~~ These results are presented in Table 5-120.

5.2.6.4 Consumption of Brown Bullhead

Data from brown bullhead was combined across two fishing zones, encompassing RMs 3-6 and 6-9, was well as combining these data to provide a Study Area wide assessment. The RME estimates ~~for~~assuming whole body consumption are (for recreational and subsistence fishers, respectively~~,~~) are 6 x 10^{-4} and 1 x 10^{-3} ~~at~~in ~~FZ~~ FZ 3-6, 6 x 10^{-4} and 4 x 10^{-3} ~~at~~in ~~FZ~~ FZ 6-9, and 2 x 10^{-3} and 4 x 10^{-3} Study Area-wide. The associated CT estimates for recreational fishers are 2 x 10^{-4} ~~at~~in FZ 3-6, 6 x 10^{-4} ~~at~~in FZ 6-9, and 5 x 10^{-4} Study Area wide.

RME r~~The comparable~~ risk estimates for recreational and subsistence fishers, respectively, assuming fillet-only consumption are 7 x 10^{-5} and 1 x 10^{-4} ~~at~~in ~~FZ~~ FZ 3-6, and 1 x 10^{-3} and 2 x 10^{-3} ~~at~~in ~~FZ~~ FZ 6-9. The ~~associated~~ Study Area-wide risk estimates ~~assuming fillet-only consumption~~ are 1 x 10^{-3} and 2 x 10^{-3}. The associated CT estimates for recreational fishers are 2 x 10^{-5} ~~at~~in FZ 3-6, 3 x 10^{-4} ~~at~~in FZ 6-9, and 3 x 10^{-4} Study Area wide. These results are presented in Table 5-116.

RME noncancer hazards associated with childhood consumption of whole body brown bullhead are greater than 1 in all instances. The RME estimates for recreational and subsistence fishers, respectively, are 40 and 70 ~~at~~in FZ 3-6, 200 and 400 ~~at~~in FZ 6-9, and 200 and 300 Study Area-wide. CT estimates for recreational fishers are 8 ~~at~~in FZ 3-6, 50 ~~at~~in FZ 6-9, and 40 Study Area-wide.

~~The comparable~~ RME hazard estimates ~~for~~assuming fillet-only consumption are 7 and 10 ~~at~~in FZ 3-6, ~~and~~ 100 and 300 ~~at~~in FZ- 6-9, and ~~. The associated Study Area-wide risk estimates assuming fillet-only consumption are~~ 100 and 300 Study Area-wide. CT estimates for recreational fishers assuming fillet-only consumption are 2 at FZ- 3-6, 30 at FZ- 6-9, and 30 Study Area-wide. ~~.~~These results are presented in Table 5-102.

~~Assuming whole body consumption of brown bullhead, the RME noncancer hazards associated with indirect exposure infants to infant children of recreational and subsistence fishers, respectively, via breastfeeding are 300 and 600 at FZ 3-6, 2,000 and 5,000 at FZ 6-9, and 2,000 and 4,000 Study Area-wide. The comparable hazard estimates assuming parental fillet-on~~Assuming whole body consumption of brown bullhead, the RME noncancer hazards associated with indirect exposure ~~infants~~ to

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infant children of recreational and subsistence fishers, respectively, via breastfeeding are 300 and 600 ~~at~~in FZ 3-6, 2,000 and 5,000 ~~at~~in FZ 6-9, and 2,000 and 4,000 Study Area-wide. CT estimates for infants of recreational fishers are 70 at FZ 3-6, 600 at FZ 6-9, and 500 Study Area-wide. The RME~~comparable~~ hazard estimates assuming parental fillet-only consumption are 70 and 100 ~~at~~in FZ 3-6, ~~and~~ 2,000 and 3,000 ~~at~~in FZ- 6-9, and 2,000 and 3,000 Study Area-wide. ~~The~~ CT estimates for infants of recreational fishers are 20 at FZ 3-6, 400 at FZ- 6-9, and 400 Study Area-wide. ~~. The associated Study Area-wide risk estimates assuming fillet-only consumption are 2,000 and 3,000ly consumption are 70 and 100 at FZ 3-6, and 2,000 and 3,000 at FZ 6-9. The associated Study Area-wide risk estimates assuming fillet-only consumption are 2,000 and 3,000.~~ These results are presented in Table 5-121.~~The estimated CT and RME cancer risks associated with combined child and adult consumption of whole body common carp are greater than 1×10^{-4} at each fishing zone evaluated, and RME cancer risk estimates are greater than 1×10^{-4}. Values for fishing zones having the highest estimated risks are as follows (RME estimates for recreational and subsistence fishers, respectively): FZ 3-6 (1×10^{-2} and 2×10^{-2}), FZ 4-8 (3×10^{-2} and 7×10^{-2}, and FZ 8-12 (2×10^{-3} and 5×10^{-3}). The associated Study Area-wide risk estimates are 4×10^{-2} and 2×10^{-2}. The comparable risk estimates for fillet-only consumption are FZ 3-6 (1×10^{-3} and 2×10^{-3}), FZ 4-8 (2×10^{-2} and 4×10^{-2}, and FZ 8-12 (1×10^{-3} and 2×10^{-3}). The associated Study Area-wide risk estimates assuming fillet-only consumption are 4×10^{-2} and 2×10^{-2}.~~

~~RME noncancer hazards associated with childhood consumption of whole body common carp are greater than 1 at each fishing zone evaluated. Values for fishing zones having the highest estimated risks are as follows (RME estimates for recreational and subsistence fishers, respectively): FZ 3-6 (2,000 and 900), FZ 4-8 (5,000 and 3,000, and FZ 8-12 (400 and 200). The comparable hazard estimates for fillet-only consumption are: FZ 3-6 (200 and 100), FZ 4-8 (4,000 and 2,000, and FZ 8-12 (200 and 90). PCBs are the primary contributors to the hazard estimates.~~

~~RME noncancer hazards associated with indirect exposure to infants via breastfeeding are greater than 100 at each fishing zone evaluated. Values for fishing zones having the highest estimated risks are as follows (infant children of recreational and subsistence fishers, respectively): FZ 3-6 (20,000 and 10,000), FZ 4-8 (60,000 and 30,000, and FZ 8-12 (3,000 and 1,000). The comparable hazard estimates associated with fillet-only consumption are: FZ 3-6 (3,000 and 1,000), FZ 4-8 (50,000 and 30,000, and FZ 8-12 (2,000 and 1,000). PCBs are the primary contributors to the hazard estimates.~~

5.2.6.5 Consumption of Black Crappie

Data from black crappie was also combined across two fishing zones, encompassing RMs 3-6 and 6-9, was well as combining these data to provide a Study Area wide assessment. ~~The~~ RME estimates assuming whole body consumption for recreational and subsistence fishers, respectively, are 3×10^{-4} and 6×10^{-4} ~~at~~in FZ 3-6, 6×10^{-4} and 1×10^{-3} ~~at~~in FZ 6-9, and 6×10^{-4} and 1×10^{-3} Study Area-wide. The

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Formatted: Normal, Indent: Left: 0.5", No bullets or numbering, Don't adjust space between Latin and Asian text, Don't adjust space between Asian text and numbers comparable CT estimates for recreational fishers are 9 x 10^{-5} in FZ 3-6, 2 x 10^{-4} in FZ 6-9, and 2 x 10^{-4} Study Area-wide.

RME risk estimates ~~for~~assuming fillet-only consumption are 3 x 10^{-5} and 6 x 10^{-5} at FZ 3-6~~-~~, ~~and~~ 4 x 10^{-5} and 8 x 10^{-5} ~~at~~in FZ 6-9, and ~~.~~4 x 10^{-5} and 8 x 10^{-5}~~T~~. ~~he associated Study Area-wide risk estimates assuming fillet-only consumption are 4 x 10^{-5} and 8 x 10^{-5}.~~ CT estimates for recreational fishers are 9 x 10^{-6} in FZ 3-6, 1 x 10^{-5} in FZ 6-9, and 1 x 10^{-5} Study Area-wide These results are presented in Table 5-117.

RME noncancer hazards associated with childhood consumption of whole body black crappie are greater than 1 in all instances. The RME estimates for recreational and subsistence fishers, respectively, are 20 and 40 ~~at~~in FZ 3-6, 40 and 80 ~~at~~in FZ 6-9, and 40 and 80 Study Area-wide. CT estimates for recreational fishers are 8 in FZ 3-6, 50 in FZ 6-9, and 40 Study Area-wide.

~~The comparable hazard estimates~~RME hazard estimates assuming childhood ~~for~~ fillet-only consumption for recreational and subsistence fishers, respectively, are 4 and 8 at FZ 3-6, and 6 and 10 at FZ-6-9. The associated Study Area-wide risk estimates assuming fillet-only consumption are 6 and 10.- CT estimates for recreational fishers assuming fillet-only consumption are 2 in FZ 3-6, 30 in FZ 6-9, and 30 Study Area-wide. These results are presented in Table 5-102.

Assuming adult whole body consumption of black crappie, the RME noncancer hazards associated with indirect exposure infants to infant children of recreational and subsistence fishers, respectively, via breastfeeding are 100 and 300 at FZ 3-6, 400 and 700 at FZ 6-9, and 400 and 700 Study Area-wide. CT estimates for infants of recreational fishers assuming fillet-only consumption are 70 in FZ 3-6, 600 in FZ 6-9, and 500 Study Area-wide.

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~~The comparable~~RME hazard estimates for infants of recreational and subsistence fishers, respectively, assuming parental fillet-only consumption are 30 and 60 at FZ 3-6, and 40 and 80 at FZ- 6-9. The associated Study Area-wide risk estimates assuming fillet-only consumption are 40 and 80. These results are presented in Table 5-121.

5.2.6.6 Multi-Species Diet

A multi-species diet, comprised of equal proportions of each of smallmouth bass, common carp, brown bullhead, and black crappie was evaluated on a harbor-wide basis. The estimated recreational fisher CT and RME cancer risk~~s~~ estimates for combined child and adult consumption of whole body fish are 2 x 10^{-3} and 7 x 10^{-3}, respectively, and the estimated risk~~s~~ for subsistence fishers is 1 x 10^{-2}. The corresponding CT and RME risk ~~risks~~estimates for recreational fishers based on fillet-only -consumption are ~~are~~ 1 x 10^{-3} and 6 -x 10^{-3}~~-~~, respectively. The estimated risk~~s~~ for subsistence fishers is 1 x 10^{-2}. PCBs, dioxins/furans, and ~~organochlorine~~

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~~pesticides~~DDx are the primary contributor to the risk estimates~~.~~. These results are presented in Table 5-118.~~.~~

The RME noncancer hazard estimates for childhood consumption of whole body fish for recreational and subsistence fishers are 600 and 1,000, respectively. The associated RME estimates for fillet-only consumption are 500 and 1,00, respectively. PCBs are the primary contributors to the hazard estimates. These results are presented in Table 5-110.

The RME noncancer hazard estimates for indirect exposure by infants via breastfeeding assuming maternal consumption of whole body fish are 8,000 for recreational fishing and 10,000 for subsistence fishing. The associated RME estimates associated with maternal fillet-only consumption are 7,000 for recreational fishing and 1,000 for subsistence. PCBs are the primary contributors to the hazard estimates. These results are presented in Table 5-123

~~The CT and RME noncancer hazard estimates for childhood consumption of whole body fish are 100 and 600, respectively, for recreational fishers. . The estimated RME hazard estimate for subsistence fishers is 1,000. . The associated CT and RME estimates for fillet-only consumption are 100 and 500 for recreational fishers, and the RME estimate for subsistence fishers is 1,000. . PCBs are the primary contributors to the hazard estimates. These results are presented in Table 5-110.~~

~~The CT and RME noncancer hazard estimates for indirect exposure by infants via breastfeeding assuming maternal consumption of whole body fish are 2,000 and 8,000, respectively, for recreational fishing. . The estimated RME hazard estimate associated with subsistence fishing is 10,000. . The associated CT and RME estimates associated with maternal fillet-only consumption are 2,000 and 7,000 for recreational fishing, and the RME estimate for subsistence fishing is 1,000. . PCBs are the primary contributors to the hazard estimates. These results are presented in Table 5-123.~~

5.2.6.7 Consumption of Clams

The estimated ~~CT and~~ RME cancer risks associated ~~with combined child and adult consumption of whole body smallmouth bass~~consumption of undepurated clams by subsistence fishers are greater than 1 x 10^{-4} ~~for all~~at 10 of the 22 river mile~~s~~ sections evaluated~~, and RME cancer risk estimates are greater than 1 x 10^{-3} for each river mile except RM 5, where the estimated risk is 9 x 10^{-4} for the recreational fisher~~. Values for river miles having the highest estimated risks are as follows~~(for recreational and subsistence fishers, respectively)~~: RM- ~~7~~5W (~~5~~6 x $10^{-\cancel{3}4}$ ~~and 1 x 10^{-2}~~), ~~Swan Island Lagoon (5 x 10^{-3} and 1 x 10^{-2}, and RM~~ RM ~~11~~6E (~~8~~7 x $10^{-\cancel{3}4}$ ~~and 2 x 10^{-2}~~), and ~~RM~~ RM 6W (7 x 10^{-4}). ~~RME risk estimates for fillet-only consumption range upwards from 9 x 10^{-5} and 2 x 10^{-4}, respectively, at RM 5. River miles having the highest estimated risks are: RM 7 (8 x 10^{-4} and 2 x 10^{-3}) and RM 11 (1 x 10^{-3} and 3 x 10^{-3}), fillet-only data were not collected in Swan Island Lagoon. Study Area-wide RME~~

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~~risks for recreational and subsistence fishers are 3 x 10^{-3} and 6 x 10^{-3}.~~ Other areas where the estimated risk is equal to or greater than 1 x 10^{-4} are RMs~~-~~ 2E, 3E, 4E, 4W, 7W, 8W, Swan Island Lagoon, 9W, and 11E. -The estimated risk Study Area-wide is 4 x 10^{-4}. ~~Dioxins/furans~~Carcinogenic PAHs and PCBs are generally the primary contributors to the overall risk, cPAHs are the primary contributors to the risk estimates at RMs- 5W and 6W. -a~~s~~t RM- 7, PCBs~~,~~ and ~~to a lesser degree~~ dioxins/furans~~,~~ are the primary contributors in Swan Island Lagoon and at RM- 11. These results are presented in Table 5-126.

The estimated RME noncancer hazards associated consumption of undepurated clams by subsistence fishers are greater than 1 at 20 of the 22 river mile sections evaluated. Values for river miles having the highest noncancer hazard are as follows: ~~RM~~ RM 3E- (8), ~~RM~~ RM 6E (40), ~~RM~~ RM 9W (8), and ~~RM~~ RM 11E (10). The estimated noncancer hazard Study Area-wide is 9. ~~C~~Although ~~arcinogenic~~ cPAHs and PCBs are generally the primary contributors to the overall ~~risk~~hazard, cPAHs are the primary contributors to the ~~risk~~hazard estimates at RMs 5W and 6W. ~~at RM RM 7,~~ PCBs and dioxins/furans are the primary contributors in Swan Island Lagoon at RM 7 and at ~~RM~~ RM 11.~~RME noncancer hazards associated with childhood consumption of whole body smallmouth bass are greater than 1 at all river miles evaluated. Areas with the highest estimated hazard displays a pattern similar to those with highest cancer risks. Values for river miles having the highest estimated hazard are as follows (for recreational and subsistence fishers, respectively): RM 2 (300 and 600), Swan Island Lagoon (500 and 1,000), and RM 11 (700 and 1,000). RME hazard estimates for fillet-only consumption are also greater than 1 at all river miles. The lowest hazard estimate is 9, at RM 5. Values for river miles having the highest estimated hazard for fillet-only consumption are as follows (for recreational and subsistence fishers, respectively): RM 4 (30 and 60), RM 7 (50 and 90), and RM 11 (100 and 300); fillet-only data were not collected in Swan Island Lagoon. PCBs and dioxin/furans are the primary contributors to the hazard estimates.~~ These results are presented in Table 5-126.

RME noncancer hazard associated with indirect exposure to infants via breastfeeding was also assessed, and the estimated hazard is greater than 1 at each river ~~middle~~mile evaluated.~~.~~ Values for river miles having the highest estimated hazard due to parental consumption of ~~whole body smallmouth bass~~clams are as follows (for infant children of ~~recreational and~~ subsistence fishers~~, respectively~~): ~~RM~~ RM 2E (~~400 and 2,000~~20), ~~RM~~ RM ~~7~~6E (~~600 and 3,000~~200), ~~Swan Island Lagoon (1,000 and 6,000),~~ and ~~RM~~ RM 11E (~~2,000 and 8,000~~50)~~). The comparable hazard estimates associated with fillet-only consumption are: RM 4 300 and 600), RM 7 (300 and 600), and RM 11 (2,000 and 4,000); fillet-only data were not collected in Swan Island Lagoon. PCBs are the primary contributors to the estimated noncancer hazard estimates~~. These results are presented in Table 5-132.

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5.2.6.8 Consumption of Crayfish

The estimated RME cancer risks associated consumption of crayfish by subsistence fishers are greater than 1 x 10^{-4} at ~~2~~two of the 32 individual stations evaluated: 07R006 -(3 x 10^{-4}) located at ~~RM~~ RM 7W, and CR11E (3 x 10^{-4}) located at ~~RM~~ RM 11E. When evaluated Study Area-wide, the estimated risk is 3 x 10^{-4}. ~~Carcinogenic PAHs and PCBs are generally the primary contributors to the overall risk, cPAHs are the primary contributors to the risk estimates at RMs 5W and 6W. at RM 7, PCBs and dioxins/furans are the primary contributors in Swan Island Lagoon and at RM 11~~Dioxins/furans are the primary contributors to the estimated risk at 07R006, PCBs are the primary contributors at CR11E. These results are presented in Table 5-129.

The estimated RME noncancer hazards associated consumption of ~~undepurated clams~~ crayfish by subsistence fishers are greater than 1 at ~~at 20 of the 22 river mile sections evaluated~~six of the 32 individual stations. ~~Values for river miles having the noncancer hazard are as follows: RM 3E (8), RM 6E (40), RM 9W (8), and RM 11E (10).~~Stations having the highest estimated hazard are 03R005 (4) located at the end of the International Slip, 07R006 (6), and CR11E (20). The estimated noncancer hazard Study Area-wide is ~~9~~10. ~~Carcinogenic PAHs and~~ PCBs are generally the primary contributors to the ~~overall risk, cPAHs are the primary contributors to the risk estimates at RMs 5W and 6W. at RM 7,~~ noncancer hazard at 03R005 and CR11E, ~~PCBs and~~ dioxins/furans are the primary contributors ~~in Swan Island Lagoon and at RM 11. PCBs and dioxin/furans are the primary contributors to the hazard estimates~~at 07R006. These results are presented in Table 5-129.

RME noncancer hazard associated with indirect exposure to infants via breastfeeding ~~was also assessed, and the estimated hazard~~ is greater than 1 at ~~each~~17 of the 32 stations ~~river middle~~ evaluated. Values ~~for river miles~~at locations having the highest estimated hazard due to parental consumption of clams are as follows (for infant children of subsistence fishers): ~~RM 2E (20), RM 6E (200), and RM 11E (50)~~02R001 (20) at ~~RM~~ RM 2E, 03R003 (20) at ~~RM~~ RM 3E, 03R005 (60) at ~~RM~~ RM 3E, 07R006 (20) at ~~RM~~ RM 7W. 09R002 (30) at ~~RM~~ RM 9W, and CR11E (400) at ~~RM~~ RM 11E. The hazard is 200 when evaluated Study Area-wide. These results are presented in Table 5-133.

5.2.7 Tribal Fishers

~~Recreational and subsistence~~Tribal fishers were evaluated ~~for exposures associated with~~assuming direct exposure to contaminants in sediment and via consumption of fish ~~and shellfish~~. E~~As discussed in Section 3.2.1.6,~~ exposures associated with beach sediment were assessed at individual beaches ~~designated as potential transient or recreational use areas~~, in-water sediment exposures were evaluated on a one-half river mile basis per side of the river and as an averaged, Study Area-wide evaluation. Fish consumption was evaluated assuming a multi-species diet consisting of anadromous and resident fish species, and fishing was evaluated on a Study Area-wide basis. –

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5.2.7.1 Sediment – Direct Contact

The estimated CT and RME cancer risks associated with direct contact to beach sediment is less than 1 x 10^{-4} at all beaches evaluated. The estimated RME cancer risk associated with exposure to in-water sediment is greater than 1 x 10^{-4} at two locations: ~~RM~~ RM 6W (2 x 10^{-4}) and ~~RM~~ RM 7W (3 x 10^{-4}). PAHs are the primary contributors to the risk estimate at ~~RM~~ RM 6W, dioxins/furans are the primary contributors at ~~RM~~ RM 7W~~.~~. These results are presented in Table 5-12 and 5-13.

With the exception of in-water sediment exposure at ~~RM~~ RM 7W, the estimated non-cancer hazard is less than one at all beach and in-water locations evaluated~~.~~. The estimated hazard is 3 at ~~RM~~ RM 7W, and dioxins/furans are the primary contributors to the estimate. These results are presented in Tables 5-12 and 5-13.

Noncancer RME hazard estimates associated with indirect exposure to infants via breastfeeding was evaluated ~~only for~~assuming maternal exposure to ~~contamination found in~~ in-water sediment. The estimated hazard is greater than 1 at 3 locations, ~~RM~~ RM 7W (5), ~~RM~~ RM 8.5 (4), and ~~RM~~ RM 11E (2). These results are presented in Table 5-40.

5.2.7.2 Fish Consumption

The estimated RME cancer risks ~~associated consumption of crayfish by subsistence fishers are greater than~~for the combined child and adult exposure is ~~1~~2 x 10^{-42} ~~at two of the 32 individual stations evaluated: 07R006 (3 x 10^{-4}) located at RM 7W, and CR11E (3 x 10^{-4}) located at RM 11E. When evaluated Study Area-wide, the estimated risk~~assuming whole body consumption, and ~~is 3~~1 x 10^{-42} assuming consumption of fillets only~~.~~ PCBs, and to a lesser extent ~~D~~dioxins/furans are the primary contributors to the overall risk estimates. These results are presented in Table 5-71.

The RME noncancer hazard associated with childhood consumption of whole body fish is 800, and is 600 assuming consumption of fillets only. PCBs, and to a lesser extent dioxins/furans, arsenic, and DDx are the primary contributors to the overall risk estimates. These results are presented in Table 5-69.

The RME noncancer hazard associated with indirect exposure of tribal infants via breastfeeding assuming maternal consumption of whole body fish is 9,000, and is 8,000 assuming maternal fillet-only consumption. PCBs are the primary contributors to the hazard estimates. These results are presented Table 5-72.

5.2.8 Domestic Water Use

Use of surface water as a source of household water for drinking and other domestic uses was evaluated using data from five transect and 15 single point sampling locations, as well as averaged over a Study Area-wide basis. -The estimated cancer risk for combined child and adult exposures is greater than 1 x 10^{-4} at W031

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(3 x 10^{-4}), located at ~~RM~~ RM 6W. PAHs are the primary contributor to the estimated cancer risk. However, dermal exposure is the primary pathway contributing to the risk estimate, and as described in EPA 2004, the physical-chemical properties of several PAHs, including benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, dibenzo(a,h)anthracene, and indeno(1,2,3-c,d)pyrene), place them outside of the Effective Prediction Domain used to estimate the absorbed dermal dose from water. Although PAHs are direct-acting carcinogens, the risk estimates associated with estimating dermal absorption from water have a greater degree of uncertainty than the other risk estimates presented in this BHHRA. These results are presented in Table 5-62.

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The estimated noncancer hazard based on childhood exposure is equal to or greater than 1 at several sampling locations: W005 (1) at ~~RM~~ RM 4E, W023 (1) at ~~RM~~ RM 11, W027 (2) near the mouth of Multnomah Channel, and W035 (2) in Swan Island Lagoon.- ~~IN~~In all instances, MCPP is the primary contributor to the estimated hazard. These results are presented in Table 5-59.

~~Sediment exposures were further assessed as CT and RME evaluations by assuming either a low- or a high-frequency rate of fishing. The estimated CT and RME cancer risks associated with combined child and adult consumption of whole body common carp are greater than 1 x 10^{-4} at each fishing zone evaluated, and RME cancer risk estimates are greater than 1 x 10^{-4}. Values for fishing zones having the highest estimated risks are as follows (RME estimates for recreational and subsistence fishers, respectively): FZ 3-6 (1 x 10^{-2} and 2 x 10^{-2}), FZ 4-8 (3 x 10^{-2} and 7 x 10^{-2}, and FZ 8-12 (2 x 10^{-3} and 5 x 10^{-3}). The associated Study Area-wide risk estimates are 4 x 10^{-2} and 2 x 10^{-2}. The comparable risk estimates for fillet-only consumption are FZ 3-6 (1 x 10^{-3} and 2 x 10^{-3}), FZ 4-8 (2 x 10^{-2} and 4 x 10^{-2}, and FZ 8-12 (1 x 10^{-3} and 2 x 10^{-3}). The associated Study Area-wide risk estimates assuming fillet-only consumption are 4 x 10^{-2} and 2 x 10^{-2}.~~

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~~RME noncancer hazards associated with childhood consumption of whole body common carp are greater than 1 at each fishing zone evaluated. Values for fishing zones having the highest estimated risks are as follows (RME estimates for recreational and subsistence fishers, respectively): FZ 3-6 (2,000 and 900), FZ 4-8 (5,000 and 3,000, and FZ 8-12 (400 and 200). The comparable hazard estimates for fillet-only consumption are: FZ 3-6 (200 and 100), FZ 4-8 (4,000 and 2,000, and FZ 8-12 (200 and 90). PCBs are the primary contributors to the hazard estimates.~~

~~RME noncancer hazards associated with indirect exposure to infants via breastfeeding are greater than 100 at each fishing zone evaluated. Values for fishing~~

~~zones having the highest estimated risks are as follows (infant children of recreational and subsistence fishers, respectively): FZ 3-6 (20,000 and 10,000), FZ 4-8 (60,000 and 30,000, and FZ 8-12 (3,000 and 1,000). The comparable hazard estimates associated with fillet-only consumption are: FZ 3-6 (3,000 and 1,000), FZ 4-8 (50,000 and 30,000, and FZ 8-12 (2,000 and 1,000). PCBs are the primary contributors to the hazard estimates. The comparable hazard estimates Study Area-wide are 30,000 and 50,000, respectively.~~

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~~The estimated CT and RME cancer risks associated with combined child and adult consumption of whole body common carp are greater than 1×10^{-4} at each fishing zone evaluated, and RME cancer risk estimates are greater than 1×10^{-4}. Values for fishing zones having the highest estimated risks are as follows (RME estimates for recreational and subsistence fishers, respectively): FZ 3-6 (1×10^{-2} and 2×10^{-2}), FZ 4-8 (3×10^{-2} and 7×10^{-2}, and FZ 8-12 (2×10^{-3} and 5×10^{-3}). The associated Study Area-wide risk estimates are 4×10^{-2} and 2×10^{-2}. The comparable risk estimates for fillet-only consumption are FZ 3-6 (1×10^{-3} and 2×10^{-3}), FZ 4-8 (2×10^{-2} and 4×10^{-2}, and FZ 8-12 (1×10^{-3} and 2×10^{-3}). The associated Study Area-wide risk estimates assuming fillet-only consumption are 4×10^{-2} and 2×10^{-2}.~~

~~RME noncancer hazards associated with childhood consumption of whole body common carp are greater than 1 at each fishing zone evaluated. Values for fishing zones having the highest estimated risks are as follows (RME estimates for recreational and subsistence fishers, respectively): FZ 3-6 (2,000 and 900), FZ 4-8 (5,000 and 3,000, and FZ 8-12 (400 and 200). The comparable hazard estimates for fillet-only consumption are: FZ 3-6 (200 and 100), FZ 4-8 (4,000 and 2,000, and FZ 8-12 (200 and 90). PCBs are the primary contributors to the hazard estimates.~~

~~RME noncancer hazards associated with indirect exposure to infants via breastfeeding are greater than 100 at each fishing zone evaluated. Values for fishing zones having the highest estimated risks are as follows (infant children of recreational and subsistence fishers, respectively): FZ 3-6 (20,000 and 10,000), FZ 4-8 (60,000 and 30,000, and FZ 8-12 (3,000 and 1,000). The comparable hazard estimates associated with fillet-only consumption are: FZ 3-6 (3,000 and 1,000), FZ 4-8 (50,000 and 30,000, and FZ 8-12 (2,000 and 1,000). PCBs are the primary contributors to the hazard estimates.~~

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~~Subsistence FishersConsumption of Smallmouth Bass~~

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~~The high-frequency fisher CT scenario for beach sediment results in no exceedances of 1×10^{-6} cumulative cancer risk and no exceedances of an HI of 1.~~

~~Recreational Beach Users~~

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~~Tribal Fishers~~

~~As was done for recreational/subsistence fishers, tribal fishers were evaluated for exposures associated with direct exposure to contaminants in sediment and via consumption of fish and shellfish. Risks associated with beach sediment exposures were assessed at individual beaches designated as potential transient or recreational use areas, risks associated with in-water sediment exposures were evaluated on a one-half river mile basis per side the river and as an averaged, Study Area-wide evaluation. . The estimated RME cancer risk is 3 x 10^-4 at RM 7Ws (primarily due to dioxins and furans), the associated HIs at this location are 3 based on adult exposure, and 5 based on infant exposures via breastfeeding. Dioxins and furans are the primary contributors to the estimated hazard, and the HQ is greater than 1. are greater than 1 x 10^-4 at Tribal Fishers~~

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~~Risks for the tribal fishers were estimated separately for each beach designated as a potential transient or recreational use area, which are shown in Map 2-1. The results of the risk evaluation for tribal fisher exposure to beach sediment are presented in Tables 5-12 through 5-13.~~

~~The estimated RME cancer risks associated with low-frequency fishing exposures to either beach or in-water sediments are less than 1 x 10^-4 at all areas evaluated. Noncancer hazards associated with combined child and adult exposures are less than 1 at all locations evaluated, the noncancer hazard associated with indirect exposures to infants via breastfeeding is greater than 1 at two locations: RM 7W (2), where dioxin/furan TEQ concentrations are the primary contributor, and RM 8.5W (2), where PCBs are the primary contributor with a HQ of 1.~~

~~The tribal fisher RME scenario for beach sediment results in exceedances of 1 x 10^-6 cumulative cancer risk at 18 of 18 exposure areas. There are no exceedances of 1 x 10^-4 cancer risk for the tribal fisher RME scenario. The maximum cumulative cancer risk occurs at beaches 06B030, B003 and 04B024 (2 x 10^-5) and is primarily due to incidental ingestion of sediment containing arsenic or benzo(a)pyrene. The tribal fisher RME scenario for beach sediment resulted in no HIs greater than 1. Figures 5-6 and 5-7 show the relative risk contribution of individual COPCs for each beach, as well as total risk by river mile for tribal fisher exposure to beach sediment.~~

~~The tribal fisher CT scenario for beach sediment results in exceedances of 1 x 10^-6 cumulative cancer risk at one of the 18 exposure areas (beach 06B030) primarily due to incidental ingestion of sediment containing arsenic. There are no exceedances of 1 x 10^-4 cancer risk or HI of 1 for the tribal fisher CT scenario.~~

~~The cumulative risk exceedances of 1 x 10^-6 are primarily due to arsenic, which is naturally occurring. At the DEQ background soil concentration of 7 mg/kg, the calculated risk from arsenic would exceed 1 x 10^-6 for the tribal fisher RME~~

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~~scenarios. When a background arsenic concentration of 7 mg/kg is subtracted from detected arsenic concentrations in beach sediment from potential human use areas, resulting cumulative risks for the tribal fisher RME scenario exceed 1 x 10^{-6} at eight beaches, due primarily to exposure to benzo(a)pyrene and total cPAHs, as shown in Map 5-2-1. Risks from exposure to cPAHs in sediment at these eight beaches range from 2 x 10^{-6} to 1 x 10^{-5}. Excluding background arsenic concentrations, exposure to beach sediment results in risks exceeding 1 x 10^{-6} from exposure to arsenic at one beach location. The maximum cumulative risk to tribal fishers from potential exposure to beach sediment excluding background contribution from arsenic is 1 x 10^{-5}, which occurs at beaches 04B024 and B003.~~

~~The results of the risk evaluation for tribal fisher exposure to in-water sediment are presented in Tables 5-23 through 5-25.~~

~~The tribal fisher RME scenario for in-water sediment results in exceedances of 1 x 10^{-6} cumulative cancer risk in 33 of 40 river mile segments within the Study Area, and from Study Area-wide exposure (see Table 5-23). The tribal fisher RME scenario for in-water sediment results in cumulative cancer risk greater than 1 x 10^{-4} at RM 6W and RM 7W. RM 7W is the location of the maximum cumulative cancer risk (3 x 10^{-4}). Risk at RM 7W is primarily due to incidental ingestion of sediment containing dioxins/furans (risk from dioxins/furan exposure is 3 x 10^{-4}); risk at RM 6W is primarily due to dermal contact with sediment containing benzo(a)pyrene (risk from benzo(a)pyrene exposure is 1 x 10^{-4}). In addition to these two contaminants, the following individual analytes also result in an individual cancer risk greater than 1 x 10^{-6} in at least one exposure area: arsenic, PCBs, benzo(b)fluoranthene, dibenzo(a,h)anthracene, benzo(a)anthracene, indeno(1,2,3-cd)pyrene.~~

~~Exposure areas including river mile segments outside of the Study Area that result in risks above 1 x 10^{-6} from the tribal fisher RME scenario for in-water sediment are: RM 12W (includes samples from RM 12.0W – 12.2W), Multnomah Channel, and RM 1.5E (includes samples from RM 1.5E – RM 1.9E), RM 1E, and RM1W. Tribal fisher exposure to in-water sediment from river segments outside of the Study Area do not result in HIs greater than 1.~~

~~The tribal fisher CT scenario for in-water sediment results in exceedances of 1 x 10^{-6} cumulative cancer risk at two of the 40 river mile segments (RM 6W and RM 7W). There are no exceedances of 1 x 10^{-4} cancer risk for the tribal fisher CT scenario. The maximum cumulative cancer risk occurs at RM 6W (6 x 10^{-6}) and is primarily due to exposure to sediment containing benzo(a)pyrene. The tribal fisher CT scenario for in-water sediment results in no HIs greater than 1.~~

~~There are no risks greater than 1 x 10^{-6} or HIs greater than 1 for CT tribal fisher exposure to in-water sediment from river segments assessed outside of the Study Area.~~

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~~**Tribal Fishers**~~

~~Risks to tribal fishers who consume fish caught within the Study Area were evaluated for a multi-species diet that includes salmon, lamprey, and sturgeon, in addition to resident fish species. A single ingestion rate for the multi-species diet was used to evaluate risks to the tribal fish consumer. Risks were evaluated using both 95 percent UCL/max and mean Study Area-wide tissue concentrations for both fillet and whole body tissue (see Section 3.4.5). Risks were higher for whole body tissue than for fillet tissue; however, fillet tissue was not analyzed for PCB or dioxin/furan congeners in all resident species. The results of the risk evaluation for adult tribal fish consumption are presented in Tables 5-67 through 5-70. The results of the risk evaluation for child tribal fish consumption are presented in Tables 5-71 through 5-74, and the results of the risk evaluation for the combined child and adult tribal consumers of fish are presented in Tables 5-75 through 5-76.~~

~~**Tribal Adult, Fish Consumption**~~

~~The risks ranged from a cumulative cancer risk of 2 x 10^{-2} for the 95 percent UCL/max EPCs of whole body tissue to a cumulative cancer risk of 2 x 10^{-3} for the mean EPCs of fillet tissue. For all scenarios, estimated risks are above a 1 x 10^{-4} cumulative cancer risk and are primarily due to PCBs and dioxins/furans. Figure 5-8 shows the relative risk contribution of individual COPCs for both whole body and fillet tissue diets of an adult tribal consumer, and Figure 5-9 shows a comparison of total risk per tissue type.~~

~~The cumulative HIs ranged from 400 for the 95 percent UCL/max EPCs of whole body tissue to 50 for the mean EPCs of fillet tissue. For the whole body tissue, 95 percent UCL/max EPC scenario, the PCB HQ is approximately 26 times higher than any other HQ. The toxicity endpoint for PCBs is immunological and skin. The immunological- and skin-specific HIs for tribal adult consumption are the highest endpoint-specific HIs, and exceed the next highest HI by a factor of 10. Additional endpoints that exceed an HI of 1 for the tribal adult 95 percent UCL/max consumption scenario are reproduction, central nervous system (CNS), and blood.~~

~~The multi-species diet evaluated in this BHHRA included resident fish as well as salmon, sturgeon, and lamprey. Because salmon, sturgeon, and lamprey spend time outside the Study Area, the risks from ingestion of salmon, sturgeon, and lamprey cannot be conclusively associated with sources within the Study Area. However, resident fish accounted for approximately 95 percent of the cumulative risk in the whole body diet. Of the four resident fish species included in the multi-species diet, risks from ingestion of smallmouth bass and common carp were the primary contributors to the cumulative risk.~~

~~**Tribal Child, Fish Consumption**~~

~~The risks ranged from a cumulative cancer risk of 3 x 10^{-3} for the 95 percent UCL/max EPCs of whole body tissue to a cumulative cancer risk of 4 x 10^{-4} for the~~

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~~mean EPCs of fillet tissue. For all scenarios, risks are above a 1 x 10^{-4} cumulative cancer risk and are primarily due to PCBs and dioxins/furans.~~

~~The cumulative HIs ranged from 800 for the 95 percent UCL/max EPCs of whole body tissue to 100 for the mean EPCs of fillet tissue. The PCB HQ for the whole body tissue diet is approximately 26 times higher than any other HQ. The immunological- and skin- specific HIs for tribal child consumption are the maximum endpoint-specific HIs, and exceed the next highest HI by a factor of 10. Additional health endpoints that exceed an HI of one for the tribal child 95 percent UCL/max consumption scenario are reproduction, CNS, liver, and blood.~~

~~The multi-species diet evaluated in this BHHRA included resident fish as well as salmon, sturgeon, and lamprey. Because salmon, sturgeon, and lamprey spend time outside the Study Area, the calculated risks from ingestion of salmon, sturgeon, and lamprey cannot be conclusively associated with sources within the Study Area. However, resident fish accounted for approximately 95 percent of the cumulative risk associated with this scenario.~~

~~Combined Tribal Child and Adult, Fish Consumption~~

~~Cancer risks were calculated for the combined child and adult tribal fisher scenarios in order to incorporate early life exposures (EPA 2005, DEQ 2010). Cumulative cancer risks from fish consumption for the combined child and adult tribal fisher ranged from 3 x 10^{-3} (fillet tissue consumption, mean scenario) to 2 x 10^{-2}, (whole body tissue consumption, 95 percent UCL/Max scenario) primarily due to ingestion of PCBs in tissue. The results of the combined tribal child and adult cancer risks for consumption of fish tissue are presented in Tables 5-75 and 5-76.~~

~~Breastfeeding Infant of Tribal Adult Who Consumes Fish~~

~~Risks and hazards to an infant consuming human milk of a tribal adult who consumes fish were calculated for bioaccumulative compounds, consistent with EPA (2005) and DEQ (2010) guidelines. These risks are presented in Tables 5-77 and 5-78. Cancer risks range from 2 x 10^{-3} to 2 x 10^{-2}, and noncancer hazards range from 1,000 to 9,000.~~

~~Summary of Risks from Tribal Consumption of Fish~~

~~A summary of risks from tribal consumption of fish is provided in Table 5-79. Both cancer risks and noncancer hazards exceed the target risk values of 1 x 10^{-6} and 1, respectively, for all tribal receptors.~~

~~Recreational/Subsistence Fishers~~

~~Fishers~~

~~Risks for the high- and low- frequency fishers were estimated separately for each beach designated as a potential transient or recreational use area, which are shown in~~

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~~Map 2-1. The results of the risk evaluation for high-frequency fisher exposure to beach sediment are presented in Tables 5-14 through 5-15. The results of the risk evaluation for low-frequency fisher exposure to beach sediment are presented in Tables 5-16 through 5-17.~~

~~High-Frequency Fishers~~

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~~The high-frequency fisher RME scenario for beach sediment results in exceedances of 1 x 10^{-6} cumulative cancer risk at 9 of 18 exposure areas (see Table 5-14). There are no exceedances of 1 x 10^{-4} cancer risk for the high-frequency fisher RME scenario. The maximum cumulative cancer risk occurs at beaches 04B024 and 06B030 (6 x 10^{-6}) and is primarily due to incidental ingestion of sediment containing arsenic. In addition to arsenic, benzo(a)pyrene is the only other individual analyte resulting in a cancer risk greater than 1 x 10^{-6} at some exposure areas. The high-frequency fisher RME scenario for beach sediment resulted in no HIs greater than 1.~~

~~The cumulative risk exceedances of 1 x 10^{-6} are primarily due to arsenic, which is naturally occurring. At the DEQ background soil concentration of 7 mg/kg, the calculated risk from arsenic would exceed 1 x 10^{-6} for the high-frequency fisher RME scenarios. When a background arsenic concentration of 7 mg/kg is subtracted from detected arsenic concentrations in beach sediment from potential human use areas, resulting cumulative risks for the high-frequency fisher RME scenario exceed 1 x 10^{-6} at three beaches, as shown in Map 5-2-1. The maximum cumulative risk to high-frequency fishers from potential exposure to beach sediment excluding background contribution from arsenic is 3 x10^{-6}, which occurs at beaches 04B024 and B003.~~

~~The high-frequency fisher CT scenario for beach sediment results in no exceedances of 1 x 10^{-6} cumulative cancer risk and no exceedances of an HI of 1.~~

~~Low-Frequency Fishers~~

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~~The low-frequency fisher RME scenario for beach sediment results in exceedances of 1 x 10^{-6} cumulative cancer risk at six of 18 exposure areas (see Table 5-16). There are no exceedances of 1 x 10^{-4} cancer risk for the low-frequency fisher RME scenario. The maximum cumulative cancer risk occurs at beaches 06B030 and 04B024 (4 x 10^{-6}), and is primarily due to incidental ingestion of sediment containing arsenic. Besides arsenic, there are no individual analytes resulting in a cancer risk greater than 1 x 10^{-6}. The low-frequency fisher RME scenario for beach sediment resulted in no HIs greater than 1.~~

~~The cumulative risk exceedances of 1 x 10^{-6} are primarily due to arsenic, which is naturally occurring. When a background arsenic concentration of 7 mg/kg is subtracted from detected arsenic concentrations in beach sediment from potential human use areas, resulting cumulative risks for the low-frequency fisher RME scenario exceed 1 x 10^{-6} at three beaches, as shown in Map 5-2-1. The RME cumulative risk to low-frequency fishers from potential exposure to beach sediment,~~

~~excluding background contributions from arsenic, is 2 x10^{-6} at all three of these beaches.~~

~~The low-frequency fisher CT scenario for beach sediment results in no exceedances of 1 x 10^{-6} cumulative cancer risk and no exceedances of an HI of 1.~~

~~Breastfeeding Infants of Adults Exposed to Beach Sediment~~

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~~Risks and hazards to breastfeeding infants from exposure to bioaccumulative compounds in human milk were assessed for scenarios resulting in bioaccumulative compounds as COPCs. In the case of the beach sediment exposure scenarios, only the dockside worker exposures include bioaccumulative compounds as COPCs. The assessment of risks to infants entails applying a compound-specific infant risk adjustment factor (IRAF) to risks and hazards to the adult mother, in accordance with DEQ guidance (2010). Cumulative cancer risks to an infant consuming human milk from a dockside worker range from 5 x 10^{-10} to 1 x 10^{-6} across both CT and RME scenarios. Noncancer hazards range from 6 x 10^{-3} to 1 across both CT and RME scenarios. Risks to breastfeeding infants of dockside workers exposed to beach sediment are shown in Tables 5-18 through 5-19.~~

~~Fisher~~

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~~To evaluate differences in fishing frequencies, risks were evaluated for both high-frequency and low-frequency fishers. High-frequency fishers were assumed to fish from the same 1/2-mile river segment three days per week for the entire year (156 days/year) for the default residential exposure duration (30 years) for the RME. Low-frequency fishers were assumed to fish from the same 1/2-mile river segment for two days per week for the entire year (104 days/year) for the default residential exposure duration (30 years) for the RME. The results of the risk evaluation for high-frequency fisher exposure to in-water sediment are presented in Tables 5-26 through 5-28. The results of the risk evaluation for low-frequency fisher exposure to in-water sediment are presented in Tables 5-29 through 5-30.~~

~~High-Frequency Fisher~~

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~~The high-frequency fisher RME scenario for in-water sediment results in exceedances of 1 x 10^{-6} cumulative cancer risk in 17 of 40 river mile segments within the Study Area and from Study Area-wide exposure (see Table 5-26). There are no exceedances of 1 x 10^{-4} cancer risk for the high-frequency fisher RME scenario. The maximum cumulative cancer risks occur at RM 7W (8 x 10^{-5}) and RM 6W (5 x 10^{-5}). At RM 7W, risk is primarily due to incidental ingestion of sediment containing dioxins/furans. At RM 6W, risk is primarily due to dermal contact with sediment containing benzo(a)pyrene. In addition to these chemicals, the following individual analytes also result in a cancer risk greater than 1 x 10^{-6} in at least one exposure area: arsenic, PCBs, benzo(b)fluoranthene, dibenzo(a,h)anthracene, benzo(a)anthracene, and indeno(1,2,3-cd)pyrene.~~

~~For river mile segments outside of the Study Area, RM 12W is the only exposure area that results in risk above 1 x 10^{-6} for the high-frequency fisher RME scenario for in-water sediment. Risk at RM 12W is 2 x 10^{-6}, primarily due to exposure to benzo(a)pyrene. There are no exposure areas outside of the Study Area resulting in an HI greater than 1.~~

~~The high-frequency fisher CT scenario for in-water sediment results in no exceedances of 1 x 10^{-6} cumulative cancer risk and no exceedances of an HI of 1 for exposure areas assessed inside and outside of the Study Area.~~

~~Low-Frequency Fisher~~

~~The low-frequency fisher RME scenario for in-water sediment results in exceedances of 1 x 10^{-6} cumulative cancer risk at 12 of 40 river mile segments within the Study Area, and from Study Area-wide exposure (see Table 5-29). There are no exceedances of 1 x 10^{-4} cancer risk for the low-frequency fisher RME scenario. The maximum cumulative cancer risks occur at RM 7W (6 x10^{-5}) and RM 6W (3 x10^{-5}). At RM 7W, risk is primarily due to incidental ingestion of sediment containing dioxins/furans. At RM 6W, risk is primarily due to dermal contact with sediment containing benzo(a)pyrene. In addition to these chemicals, the following individual analytes also result in a cancer risk greater than 1 x 10^{-6} in at least one exposure area: PCBs, dibenzo(a,h)anthracene, benzo(a)anthracene, benzo(b)fluoranthene, and indeno(1,2,3-cd)pyrene. The low-frequency fisher RME scenario for in-water sediment results in no HIs greater than 1.~~

~~There are no risks greater than 1 x 10^{-6} or HIs greater than 1 for the low-frequency fisher RME scenario for exposure to in-water sediment from river segments assessed outside of the Study Area.~~

~~The low-frequency fisher CT scenario for in-water sediment results in no exceedances of 1 x 10^{-6} cumulative cancer risk and no exceedances of an HI of 1 for exposure areas inside and outside of the Study Area.~~

~~Domestic Water Use~~

~~6.0~~

~~5.12.1 Beach Sediment Risk Characterization Results~~

~~Potential risks from exposure to beach sediment through incidental ingestion and dermal absorption were estimated for the dockside workers, transients, recreational beach users, fishers, and tribal fishers. There were multiple uncertainties associated with the direct exposure to beach sediment scenarios such as the spatial scale of the individual beaches and the exposure parameters, which are further described in the following sections. Beaches with cumulative cancer risks greater than 1 x 10^{-6} and 1 x 10^{-5} are summarized by exposure point and receptor in Maps 5-1-1 and 5-~~

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~~1-2. There were no beach areas associated with cancer risk levels greater than 1 x 10^{-4} or HIs greater than 1.~~

~~5.12.1.1 Dockside Worker~~

~~1.0 Risks for the dockside workers were estimated separately for each beach designated as a potential dockside worker use area, which are shown in Map 2-1. The results of the risk evaluation for dockside worker exposure to beach sediment are presented in Tables 5-2 through 5-3.~~

~~2.0 The dockside worker RME scenario for beach sediment results in exceedances of a cumulative cancer risk level of 1 x 10^{-6} at beaches 06B025 (9 x 10^{-5} risk) and B004 (2 x 10^{-6} risk). There are no exposure areas that result in an exceedance of 1 x 10^{-4} cancer risk for the dockside worker RME scenario. The maximum cumulative cancer risk for an individual exposure area occurs at 06B025 and is primarily due to incidental ingestion of beach sediment containing benzo(a)pyrene. In addition to benzo(a)pyrene, other chemicals contributing to a calculated individual cancer risk greater than 1 x 10^{-6} for at least one exposure area include: benzo(a)anthracene, benzo(b)flouranthene, dibenzo(a,h)anthracene, and indeno(1,2,3-cd)pyrene. The HIs for the dockside worker RME scenario do not exceed 1.~~

~~3.0 The dockside worker CT scenario for beach sediment results in one exceedance of 1 x 10^{-6} cumulative cancer risk (at beach 06B025, 6 x 10^{-6} risk), which is primarily due to the incidental ingestion of sediment containing benzo(a)pyrene. There are no exposure areas that result in an exceedance of 1 x 10^{-4} cancer risk for the dockside worker CT beach sediment scenario. The dockside worker CT scenario results in no exceedances of a HI of 1. Figures 5-1 shows risks to the dockside worker from exposure to beach sediment per beach, and shows the relative contribution of individual chemicals to total risk.~~

~~5.12.1.2 Transients~~

~~Risks for the transients were estimated separately for each beach designated as a potential transient use area, which are shown in Map 2-1. The results of the risk evaluation for transient exposure to beach sediment are presented in Tables 5-4 through 5-5.~~

~~The transient RME scenario for beach sediment results in no exceedances of 1 x 10^{-6} cancer risk and no exceedances of a HI of 1. The transient CT scenario for beach sediment results in no exceedances of 1 x 10^{-6} cancer risk and no exceedances of a HI of 1. The results of the risk evaluation for transient exposure to beach sediment are presented in Tables 5-4 through 5-5.~~

~~5.12.1.3 Recreational Beach Users~~

~~Risks for the recreational beach users were estimated separately for each beach designated as a potential recreational use area, which are shown in Map 2-1. Cancer~~

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~~risks and noncancer hazards were evaluated for both adult and child recreational beach users. . In addition, carcinogenic risks were calculated for a combined child and adult scenario. . The results of the risk evaluation for recreational beach user exposure to beach sediment are presented in Tables 5-6 through 5-11.~~

~~5.12.1.3.1 Adult Recreational Beach Users~~

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~~The adult recreational beach user RME scenario for beach sediment results in cumulative cancer risk exceedances of 1 x x 10^{-6} at the following beaches: 04B024 (risk is 3 x x 10^{-6}), 06B030 (risk is 4 x x 10^{-6}), B003 (risk is 3 x x 10^{-6}), and B005 (risk is 2 x x 10^{-6}). . There are no exceedances of 1 x x 10^{-4} cancer risk for the adult recreational beach user RME scenario. . The maximum cumulative cancer risk from RME occurs at Beach 06B030 and is primarily due to incidental ingestion of beach sediment containing arsenic. . The adult recreational beach user RME scenario for beach sediment resulted in no HIs greater than 1. . Figures 5-2 and 5-3 show the relative risk contribution of individual COPCs for each beach, as well as total risk by river mile for adult recreational beach user exposure to beach sediment.~~

~~Arsenic is a naturally occurring metal. . The concentration for arsenic in soil recognized by DEQ to represent background levels in Oregon is 7 milligrams per kilogram (mg/kg) (DEQ 2007). . At this background concentration, the calculated risk from arsenic would exceed 1 x x 10^{-6} for the adult recreational beach user RME scenario. . When a background concentration of 7 mg/kg is subtracted from detected concentrations of arsenic in beach sediment, resulting cumulative risks for the adult recreational beach user RME scenario exceed 10^{-6} at beaches 04B024 and B003. . Beaches with risk exceedances of 1 x x 10^{-6} excluding risks from background arsenic are shown for all exposure scenarios for beach sediment in Maps 5-2-1 and 5-2-2. . In addition to risks from exposure to arsenic in beach sediment, risks from exposure to total cPAHs in beach sediment exceed 1 x x 10^{-6} at two beach locations: 04B024 (2 x x 10^{-6}) and B003 (2 x x 10^{-6}). At each of these beaches, benzo(a)pyrene is the cPAH with the highest contribution to total risks from cPAHs.~~

~~The adult recreational beach user CT scenario for beach sediment results in no exceedances of 1 x x 10^{-6} cumulative cancer risk and no exceedances of an HI of 1. .~~

~~5.12.1.3.2 Child Recreational Beach Users~~

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~~The child recreational beach user RME scenario for beach sediment results in cumulative risk exceedances of 1 x x 10^{-6} at all 15 of the exposure areas. . There are no exceedances of 1 x x 10^{-4} cancer risk for the child recreational beach user RME scenario. . The maximum cumulative cancer risk from RME occurs at beaches B003, and 04B024 (4 x x 10^{-5}) and is primarily due to dermal absorption of soil containing arsenic and benzo(a)pyrene. . The child recreational beach user RME scenario resulted in no HIs greater than 1.~~

~~The cumulative risk exceedances are due in part to arsenic, which is naturally occurring. . At the DEQ background soil concentration of 7 mg/kg, the calculated risk from arsenic would exceed 1 x x 10^{-6} for the child recreational beach user RME scenario. . When a background arsenic concentration of 7 mg/kg is subtracted from detected arsenic concentrations in beach sediment from potential human use areas, resulting cumulative risks for the child recreational beach user RME scenario exceed 1 x x 10^{-6} at five beaches, as shown in Map 5-2-1. . These exceedances are due to exposure to arsenic at one beach, and exposure to benzo(a) pyrene or total cPAHs at the other four. . Cancer risks above 1 x x 10^{-6} from exposures to cPAHs in beach sediment range from 2 x x 10^{-8} to 4 x x 10^{-5}, due primarily to contributions from benzo(a)pyrene. . Figures 5-4 and 5-5 show the relative risk contribution of individual COPCs for each beach, as well as total risk by river mile for child recreational beach user exposure to beach sediment.~~

~~The child recreational beach user CT scenario for beach sediment results in an exceedance of 1 x x 10^{-6} cumulative cancer risk at two beaches (risk of 2 x x 10^{-6} at 04B024 and B003). There are no exceedances of an HI of 1. .~~

~~5.12.1.3.3 Combined Child/Adult Recreational Beach Users~~

~~Cancer risks were calculated for the combined child and adult recreational beach users to incorporate early life exposures in accordance with EPA (2005b) and DEQ (2010) guidance. . Cumulative risks per exposure area for RME scenarios ranged from 2 x x 10^{-6} to 5 x x 10^{-5}. . For the CT scenarios, risks ranged from 2 x x 10^{-7} to 2 x x 10^{-6}. . The highest risk was at Beach 04B024, primarily due to exposures to benzo(a)pyrene in beach sediment.~~

~~5.12.1.4 Tribal Fishers~~

~~Risks for the tribal fishers were estimated separately for each beach designated as a potential transient or recreational use area, which are shown in Map 2-1. . The results of the risk evaluation for tribal fisher exposure to beach sediment are presented in Tables 5-12 through 5-13. .~~

~~The tribal fisher RME scenario for beach sediment results in exceedances of 1 x x 10^{-6} cumulative cancer risk at 18 of 18 exposure areas. . There are no exceedances of 1 x x 10^{-4} cancer risk for the tribal fisher RME scenario. . The maximum cumulative cancer risk occurs at beaches 06B030, B003 and 04B024 (2 x x 10^{-5}) and is primarily due to incidental ingestion of sediment containing arsenic or benzo(a)pyrene. . The tribal fisher RME scenario for beach sediment resulted in no HIs greater than 1. . Figures 5-6 and 5-7 show the relative risk contribution of individual COPCs for each beach, as well as total risk by river mile for tribal fisher exposure to beach sediment.~~

~~The tribal fisher CT scenario for beach sediment results in exceedances of 1 x x 10^{-6} cumulative cancer risk at one of the 18 exposure areas (beach 06B030) primarily due to incidental ingestion of sediment containing arsenic. . There are no exceedances of 1 x x 10^{-4} cancer risk or HI of 1 for the tribal fisher CT scenario.~~

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~~The cumulative risk exceedances of 1 x x 10^{-6} are primarily due to arsenic, which is naturally occurring. . At the DEQ background soil concentration of 7 mg/kg, the calculated risk from arsenic would exceed 1 x x 10^{-6} for the tribal fisher RME scenarios. . When a background arsenic concentration of 7 mg/kg is subtracted from detected arsenic concentrations in beach sediment from potential human use areas, resulting cumulative risks for the tribal fisher RME scenario exceed 1 x x 10^{-6} at eight beaches, due primarily to exposure to benzo(a)pyrene and total cPAHs, as shown in Map 5-2-1. . Risks from exposure to cPAHs in sediment at these eight beaches range from 2 x x 10^{-6} to 1 x x 10^{-5}. . Excluding background arsenic concentrations, exposure to beach sediment results in risks exceeding 1 x x 10^{-6} from exposure to arsenic at one beach location. . The maximum cumulative risk to tribal fishers from potential exposure to beach sediment excluding background contribution from arsenic is 1 x x 10^{-5}, which occurs at beaches 04B024 and B003.~~

~~5.12.1.5 Fishers~~

~~Risks for the high- and low- frequency fishers were estimated separately for each beach designated as a potential transient or recreational use area, which are shown in Map 2-1. . The results of the risk evaluation for high-frequency fisher exposure to beach sediment are presented in Tables 5-14 through 5-15. . The results of the risk evaluation for low-frequency fisher exposure to beach sediment are presented in Tables 5-16 through 5-17. .~~

~~5.12.1.5.1 High-Frequency Fishers~~

~~The high-frequency fisher RME scenario for beach sediment results in exceedances of 1 x x 10^{-6} cumulative cancer risk at 9 of 18 exposure areas (see Table 5-14). . There are no exceedances of 1 x x 10^{-4} cancer risk for the high-frequency fisher RME scenario. . The maximum cumulative cancer risk occurs at beaches 04B024 and 06B030 (6 x x 10^{-6}) and is primarily due to incidental ingestion of sediment containing arsenic. . In addition to arsenic, benzo(a)pyrene is the only other individual analyte resulting in a cancer risk greater than 1 x x 10^{-6} at some exposure areas. . The high-frequency fisher RME scenario for beach sediment resulted in no HIs greater than 1.~~

~~The cumulative risk exceedances of 1 x x 10^{-6} are primarily due to arsenic, which is naturally occurring. . At the DEQ background soil concentration of 7 mg/kg, the calculated risk from arsenic would exceed 1 x x 10^{-6} for the high-frequency fisher RME scenarios. . When a background arsenic concentration of 7 mg/kg is subtracted from detected arsenic concentrations in beach sediment from potential human use areas, resulting cumulative risks for the high-frequency fisher RME scenario exceed 1 x x 10^{-6} at three beaches, as shown in Map 5-2-1. . The maximum cumulative risk to high-frequency fishers from potential exposure~~

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~~to beach sediment excluding background contribution from arsenic is 3 x10^{-6}, which occurs at beaches 04B024 and B003.~~

- ~~The high-frequency fisher CT scenario for beach sediment results in no exceedances of 1 x x 10^{-6} cumulative cancer risk and no exceedances of an HI of 1.~~

~~5.12.1.5.2 Low-Frequency Fishers~~

- ~~The low-frequency fisher RME scenario for beach sediment results in exceedances of 1 x x 10^{-6} cumulative cancer risk at six of 18 exposure areas (see Table 5-16). . There are no exceedances of 1 x x 10^{-4} cancer risk for the low-frequency fisher RME scenario. . The maximum cumulative cancer risk occurs at beaches 06B030 and 04B024 (4 x x 10^{-6}), and is primarily due to incidental of sediment containing arsenic. . Besides arsenic, there are no individual analytes resulting in a cancer risk greater than 1 x x 10^{-6}. . The low-frequency fisher RME scenario for beach sediment resulted in no HIs greater than 1.~~

- ~~The cumulative risk exceedances of 1 x x 10^{-6} are primarily due to arsenic, which is naturally occurring. . When a background arsenic concentration of 7 mg/kg is subtracted from detected arsenic concentrations in beach sediment from potential human use areas, resulting cumulative risks for the low-frequency fisher RME scenario exceed 1 x x 10^{-6} at three beaches, as shown in Map 5-2-1. . The RME cumulative risk to low-frequency fishers from potential exposure to beach sediment, excluding background contributions from arsenic, is 2 x10^{-6} at all three of these beaches.~~

- ~~The low-frequency fisher CT scenario for beach sediment results in no exceedances of 1 x x 10^{-6} cumulative cancer risk and no exceedances of an HI of 1.~~

~~5.12.1.6 Breastfeeding Infants of Adults Exposed to Beach Sediment~~

- ~~Risks and hazards to breastfeeding infants from exposure to bioaccumulative compounds in human milk were assessed for scenarios resulting in bioaccumulative compounds as COPCs. . In the case of the beach sediment exposure scenarios, only the dockside worker exposures include bioaccumulative compounds as COPCs. . The assessment of risks to infants entails applying a compound-specific infant risk adjustment factor (IRAF) to risks and hazards to the adult mother, in accordance with DEQ guidance (2010). . Cumulative cancer risks to an infant consuming human milk from a dockside worker range from 5 x x 10^{-10} to 1 x x 10^{-6} across both CT and RME scenarios. Noncancer hazards range from 6 x x 10^{-3} to 1 across both CT and RME scenarios. . Risks to~~

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~~**breastfeeding infants of dockside workers exposed to beach sediment are shown in Tables 5-18 through 5-19.**~~

~~5.12.1.7 Summary of Beach Sediment Risk Characterization~~

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~~Direct contact with beach sediment resulted in cumulative cancer risks ranging from 8 x x 10^{-9} to 9 x x 10^{-5}. . Cumulative HIs for direct exposure to beach sediment were at or below the EPA target HI of 1 for all exposure scenarios. . The highest cumulative cancer risks at industrial use beaches were for the dockside worker scenario, and the highest cumulative cancer risks at residential use beaches were for the tribal fisher scenario. Two chemicals resulted in a cancer risk greater than 1 x x 10^{-6} for at least one of the scenarios evaluated for direct contact with beach sediment: arsenic and PAHs. . Arsenic occurs both naturally and as a result of environmental releases. . A summary of risks from beach sediment per beach is shown in Maps 5-1-1 and 5-1-2, and risks after subtracting an assumed background arsenic concentration of 7 mg/kg from the EPCs are shown in Maps 5-2-1 and 5-2-2. . Table 5-20 provides a summary of risks from exposure to beach sediment, per receptor and exposure area.~~

~~5.12.2 In-Water Sediment Risk Characterization Results~~

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~~Potential risks from exposure to in-water sediment through incidental ingestion and dermal absorption were estimated for the in-water workers, fishers, tribal fishers, and divers. . There were multiple uncertainties associated with the direct exposure to in-water sediment scenarios such as the spatial scale of the exposure areas and the exposure parameters, which are further described in the following sections. . Risks were estimated separately for in-water sediment for each of the ½-mile river segment exposure areas (east (E) and west (W)) and for Study Area-wide exposure. . In addition to calculating risks from in-water sediment exposure within the Study Area (which includes exposure areas from RM 1.9 to RM 11.8, including Swan Island Lagoon), risks from in-water sediment exposure were calculated for three river segments outside of the Study Area: the downstream reach (RM 1.0-1.9), the downtown river segment (RM 11.8 – 12.2), and Multnomah Channel. . The exposure area from RM 11.5 to 12.0 encompasses samples from both inside and outside of the Study Area. . However, Study Area-wide risks were calculated only for samples within the Study Area. . Cumulative risk exceedances for in-water sediment scenarios are summarized by exposure area in Maps 5-3-1 through 5-3-2. . In addition, risks from exposures to PBDEs in in-water sediment were evaluated separately and are presented in Attachment F3, following the general methodology discussed in this BHHRA.~~

~~5.12.2.1 In-Water Worker~~

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~~The results of the risk evaluation for in-water worker exposure to in-water sediment are presented in Tables 5-21 through 5-22. .~~

~~The in-water worker RME scenario for in-water sediment results in cumulative cancer risk greater than 1 x x 10^{-6} at RM segments 4.5E, 6W, and 7W. . There are no exceedances of 1 x x 10^{-4} cancer risk for the in-water worker RME scenario. . The maximum cumulative cancer risk for an individual exposure area occurs at RM 7W (2 x x 10^{-5}) and is primarily due to incidental ingestion of sediment containing dioxins/furans. . The only other individual contaminant resulting in a cancer risk greater than 1 x x 10^{-6} within the Study Area is benzo(a)pyrene. . The HIs for in-water worker RME scenario do not exceed 1. .~~

~~The in-water worker RME scenarios do not result in an exceedance of 1 x x 10^{-6} cumulative cancer risk or an HI greater than 1 for exposure to in-water sediment from river segments assessed outside of the Study Area.~~

~~The in-water worker CT scenario for in-water sediment results in no exceedances of 1 x x 10^{-6} cancer risk and no exceedances of an HI of 1.~~

~~5.12.2.2 Tribal Fisher~~

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~~The results of the risk evaluation for tribal fisher exposure to in-water sediment are presented in Tables 5-23 through 5-25.~~

~~The tribal fisher RME scenario for in-water sediment results in exceedances of 1 x x 10^{-6} cumulative cancer risk in 33 of 40 river mile segments within the Study Area, and from Study Area-wide exposure (see Table 5-23). . The tribal fisher RME scenario for in-water sediment results in cumulative cancer risk greater than 1 x x 10^{-4} at RM 6W and RM 7W. RM 7W is the location of the maximum cumulative cancer risk (3 x x 10^{-4}). . Risk at RM 7W is primarily due to incidental ingestion of sediment containing dioxins/furans (risk from dioxins/furan exposure is 3 x x 10^{-4}); risk at RM 6W is primarily due to dermal contact with sediment containing benzo(a)pyrene (risk from benzo(a)pyrene exposure is 1 x x 10^{-4}). . In addition to these two contaminants, the following individual analytes also result in an individual cancer risk greater than 1 x x 10^{-6} in at least one exposure area: arsenic, PCBs, benzo(b)fluoranthene, dibenzo(a,h)anthracene, benzo(a)anthracene, indeno(1,2,3-cd)pyrene. .~~

~~Exposure areas including river mile segments outside of the Study Area that result in risks above 1 x x 10^{-6} from the tribal fisher RME scenario for in-water sediment are: RM 12W (includes samples from RM 12.0W – 12.2W), Multnomah Channel, and RM 1.5E (includes samples from RM 1.5E – RM 1.9E), RM 1E, and RM1W. . Tribal fisher exposure to in-water sediment from river segments outside of the Study Area do not result in HIs greater than 1.~~

~~The tribal fisher CT scenario for in-water sediment results in exceedances of 1 x x 10^{-6} cumulative cancer risk at two of the 40 river mile segments (RM 6W and RM 7W). . There are no exceedances of 1 x x 10^{-4} cancer risk for the tribal fisher CT scenario. . The maximum cumulative cancer risk occurs at RM 6W (6 x x 10^{-6}) and~~

~~is primarily due to exposure to sediment containing benzo(a)pyrene. . The tribal fisher CT scenario for in-water sediment results in no HIs greater than 1.~~

~~There are no risks greater than 1 x x 10^{-6} or HIs greater than 1 for CT tribal fisher exposure to in-water sediment from river segments assessed outside of the Study Area.~~

~~5.12.2.3 Fisher~~

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~~To evaluate differences in fishing frequencies, risks were evaluated for both high-frequency and low-frequency fishers. . High-frequency fishers were assumed to fish from the same 1/2-mile river segment three days per week for the entire year (156 156 days/year) for the default residential exposure duration (30 years) for the RME. . Low-frequency fishers were assumed to fish from the same 1/2-mile river segment for two days per week for the entire year (104 days/year) for the default residential exposure duration (30 years) for the RME. . The results of the risk evaluation for high-frequency fisher exposure to in-water sediment are presented in Tables 5-26 through 5-28. . The results of the risk evaluation for low-frequency fisher exposure to in-water sediment are presented in Tables 5-29 through 5-30. .~~

~~5.12.2.3.1 High-Frequency Fisher~~

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~~The high-frequency fisher RME scenario for in-water sediment results in exceedances of 1 x x 10^{-6} cumulative cancer risk in 17 of 40 river mile segments within the Study Area and from Study Area-wide exposure (see Table 5-26). . There are no exceedances of 1 x x 10^{-4} cancer risk for the high-frequency fisher RME scenario. . The maximum cumulative cancer risks occur at RM 7W (8 x x 10^{-5}) and RM 6W (5 x x 10^{-5}). . At RM 7W, risk is primarily due to incidental ingestion of sediment containing dioxins/furans. . At RM 6W, risk is primarily due to dermal contact with sediment containing benzo(a)pyrene. . In addition to these chemicals, the following individual analytes also result in a cancer risk greater than 1 x x 10^{-6} in at least one exposure area: arsenic, PCBs, benzo(b)fluoranthene, dibenzo(a,h)anthracene, benzo(a)anthracene, and indeno(1,2,3-cd)pyrene. .~~

~~For river mile segments outside of the Study Area, RM 12W is the only exposure area that results in risk above 1 x x 10^{-6} for the high-frequency fisher RME scenario for in-water sediment. . Risk at RM 12W is 2 x x 10^{-6}, primarily due to exposure to benzo(a)pyrene. . There are no exposure areas outside of the Study Area resulting in an HI greater than 1.~~

~~The high-frequency fisher CT scenario for in-water sediment results in no exceedances of 1 x x 10^{-6} cumulative cancer risk and no exceedances of an HI of 1 for exposure areas assessed inside and outside of the Study Area. .~~

~~5.12.2.3.2 Low-Frequency Fisher~~

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~~The low-frequency fisher RME scenario for in-water sediment results in exceedances of 1 x x 10^{-6} cumulative cancer risk at 12 of 40 river mile segments within the Study~~

~~Area, and from Study Area-wide exposure (see Table 5-29). There are no exceedances of 1 x 10^{-4} cancer risk for the low-frequency fisher RME scenario. The maximum cumulative cancer risks occur at RM 7W (6 x10^{-5}) and RM 6W (3 x10^{-5}). At RM 7W, risk is primarily due to incidental ingestion of sediment containing dioxins/furans. At RM 6W, risk is primarily due to dermal contact with sediment containing benzo(a)pyrene. In addition to these chemicals, the following individual analytes also result in a cancer risk greater than 1 x 10^{-6} in at least one exposure area: PCBs, dibenzo(a,h)anthracene, benzo(a)anthracene, benzo(b)fluoranthene, and indeno(1,2,3-cd)pyrene. The low-frequency fisher RME scenario for in-water sediment results in no HIs greater than 1.~~

~~There are no risks greater than 1 x 10^{-6} or HIs greater than 1 for the low-frequency fisher RME scenario for exposure to in-water sediment from river segments assessed outside of the Study Area.~~

~~The low-frequency fisher CT scenario for in-water sediment results in no exceedances of 1 x 10^{-6} cumulative cancer risk and no exceedances of an HI of 1 for exposure areas inside and outside of the Study Area.~~

~~5.12.2.4 Diver~~

~~Risks were evaluated for commercial divers wearing either a wet suit or a dry suit. The results of the risk evaluation for commercial wet suit diver exposure to in-water sediment are presented in Tables 5-31 through 5-32. The results of the risk evaluation for a commercial dry suit diver exposure to in-water sediment are presented in Table 5-33.~~

~~5.12.2.4.1 Diver in Wet Suit~~

~~The commercial diver in a wet suit RME scenario for in-water sediment results in exceedances of 1 x 10^{-6} cumulative cancer risk in 10 of 40 ½-mile river mile segments within the Study Area and for Study Area-wide exposure (see Table 5-31). There are no exceedances of 1 x 10^{-4} cancer risk for this scenario. The maximum cumulative cancer risk (3 x 10^{-5}) occurs at RM 6W and RM 7W. At RM 6W, the risk is primarily due to dermal adsorption of sediment containing benzo(a)pyrene. At RM 7W, the risk is primarily due to dermal absorption of sediment containing dioxins and furans. In addition to these two chemicals, the following individual analytes also result in a cancer risk greater than 1 x 10^{-6} in at least one exposure area: PCBs, benzo(b)fluoranthene, dibenzo(a,h)anthracene, benzo(a)anthracene, and indeno(1,2,3-cd)pyrene. The commercial diver in a wet suit RME scenario for in-water sediment results in no HIs greater than 1.~~

~~There are no exposure areas outside of the Study Area that result in risks above 1 x 10^{-6} or HIs greater than 1 for this scenario.~~

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~~The commercial diver in a wet suit CT scenario for in-water sediment results in no exceedances of 1 x x 10^{-6} cumulative cancer risk and no exceedances of an HI of 1 for exposure areas assessed inside and outside of the Study Area (see Table 5-32).~~

~~5.12.2.4.2 Diver in Dry Suit~~

~~The commercial diver in a dry suit RME scenario for in-water sediment results in exceedances of 1 x x 10^{-6} cumulative cancer risk in two of 40 river mile segments within the Study Area (see Table 5-33). The maximum cumulative cancer risks occur at RM 7W (1 x x 10^{-5}) and RM 6W (6 x x 10^{-6}). At RM 7W, risk is primarily due to incidental ingestion of sediment containing dioxins/furans. At RM 6W, risk is primarily due to dermal contact with sediment containing benzo(a)pyrene. No other analytes result in a cancer risk greater than 1 x x 10^{-6} for this scenario. The commercial diver in a dry suit RME scenario for in-water sediment results in no HIs greater than 1. There are no river mile segments outside of the Study Area that result in risk above 1 x x 10^{-6} or an HI greater than 1. A CT scenario was not evaluated for a commercial diver in a dry suit, per direction from EPA.~~

~~5.12.2.5 Breastfeeding Infants of Adults Exposed to In-Water Sediment~~

~~Risks to infants consuming breastmilk from adults exposed to in-water sediment were calculated for all adult receptors for which bioaccumulative compounds were COPCs. This included all receptors assessed in this BHHRA for direct exposure to in-water sediment. These risk results are shown in Tables 5-34 through 5-44. The highest cumulative cancer risk to breastfeeding infants of adults exposed to in-water sediment occurs at RM 7W, due to consumption of dioxin/furans in human milk of a tribal fisher exposed to in-water sediment. The highest noncancer hazard to an infant also occurs at RM 7W (HI is 5).~~

~~5.12.2.6 Summary of In-Water Sediment Risk Characterization~~

~~Direct contact with in-water sediment resulted in cumulative cancer risks ranging from 5 x x 10^{-9} to 3 x x 10^{-4} across all scenarios. The only HI that was greater than 1 was for the tribal fisher and high frequency fisher RME scenario due to dioxin/furans, which occurred at the ½-mile exposure area at RM 7 west (W). The highest cumulative cancer risks and HIs from direct contact with in-water sediment were for the tribal fisher scenario. Four contaminants resulted in a cancer risk greater than 1 x x 10^{-6} or hazard quotient greater than 1 for at least one of the in-water sediment scenarios: PCBs, dioxins, arsenic, and PAHs. A summary of in-water sediment risks by receptor and analyte are shown in Table 5-45.~~

~~5.12.3 Surface Water Risk Characterization Results~~

~~Potential risks from exposure to surface water through ingestion and dermal absorption were estimated for transients, recreational beach users, and divers. In addition, potential risks were estimated for a hypothetical future use of surface water as a domestic water source. There were multiple uncertainties associated with the direct exposure to surface water scenarios such as the exposure parameters, which are~~

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~~further described in the following sections, and contributions from background sources.~~

~~5.12.3.1 Transients~~

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~~Risks to transients from surface water were evaluated for drinking water and bathing scenarios. .The risks were evaluated for year-round exposure to surface water for four individual transect stations, for the four transects grouped together (to represent Study Area-wide exposure), and for Willamette Cove. .In addition to these exposure areas within the Study Area, risk was evaluated for exposure to surface water for a transect in Multnomah Channel, which is outside of the Study Area. .The results of the risk evaluation for transient exposure to surface water are presented in Tables 5-46 through 5-47.~~

~~The transient RME and CT scenarios for surface water result in no exceedances of 1 x x 10~~$^{-6}$ ~~cancer risk and no exceedances of an HI of 1 inside or outside of the Study Area. .~~

~~5.12.3.2 Recreational Beach Users~~

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~~Risks to recreational beach users from surface water were evaluated for swimming scenarios, using data from summer months. .Risks were evaluated for exposure to surface water for three transects grouped together (to represent Study Area-wide exposure) and for exposure to surface water for three individual quiescent areas during summer months. .Risks for both adults and children were evaluated, as well as cancer risks to a combined child and adult receptor, in order to incorporate early-life exposures. .The results of the risk evaluation for adult recreational beach user exposure to surface water are presented in Tables 5-48 through 5-49. .The results of the risk evaluation for child recreational beach user exposure to surface water are presented in Tables 5-50 through 5-51. .The results of the combined child and adult receptor are presented in Tables 5-52 through 5-53.~~

~~The adult, child, and combined recreational beach user RME and CT scenarios for surface water result in no exceedances of 1 x x 10~~$^{-6}$ ~~cancer risk and no exceedances of an HI of 1. .~~

~~5.12.3.3 Diver~~

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~~Risks to commercial divers from surface water were evaluated for year-round exposure to four individual transect stations, and to single-point sampling stations within the Study Area grouped together on a ½-river mile basis, per side of river (E, W). .In addition to these exposure areas within the Study Area, risk was evaluated for exposure to surface water for a transect in Multnomah Channel, which is outside of the Study Area. .Risks were evaluated for commercial divers in wet suits and in dry suits. .The results of the risk evaluation for commercial divers in wet suits exposure to surface water are presented in Tables 5-54 through 5-55. .The results of the risk evaluation for commercial divers in dry suits are presented in Table 5-56.~~

~~5.12.3.3.1 Diver in Wet Suit~~

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~~The commercial diver in a wet suit RME scenario for surface water results in exceedances of 1 x x 10^{-6} cumulative cancer risk in one exposure area (RM 6W). . There are no exceedances of 1 x x 10^{-4} cancer risk for the commercial diver in a wet suit RME scenario. . The maximum cumulative cancer risk occurs at RM 6W (1 x x 10^{-5}) and is primarily due to dermal contact with surface water containing benzo(a)pyrene. . There are no other analytes resulting in a cancer risk greater than 1 x x 10^{-6}. . The commercial diver in a wet suit RME scenario for surface water resulted in no HIs greater than 1. . There are no exceedances of 1 x x 10^{-6} risk or an HI of 1 for surface water exposure to river segments assessed outside of the Study Area.~~

~~The commercial diver in a wet suit CT scenario for surface water results in no exceedances of 1 x x 10^{-6} cumulative cancer risk and no exceedances of an HI of 1 for exposure inside or outside of the Study Area. .~~

~~5.12.3.3.2 Diver in Dry Suit~~

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~~The commercial diver in a dry suit RME scenario for surface water results in exceedances of 1 x x 10^{-6} cumulative cancer risk in one exposure area (RM 6W). . This exposure area is the location of the maximum cumulative cancer risk (2 x x 10^{-6}) and is primarily due to dermal contact with surface water containing benzo(a)pyrene. . There are no individual analytes resulting in a cancer risk greater than 1 x x 10^{-6}. . The commercial diver in a dry suit RME scenario for surface water resulted in no HIs greater than 1. . There are no exceedances of 1 x x 10^{-6} risk or an HI of 1 for surface water exposure to river segments assessed outside of the Study Area.~~

~~The commercial diver in a dry suit was not evaluated for CT exposure, as directed by EPA.~~

~~5.12.3.4 Domestic Water User~~

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~~There is no known or anticipated future use of surface water within the Study Area for a domestic water supply. . Because the designated beneficial use of the Willamette River is as a domestic water supply with adequate pretreatment, EPA directed that surface water be evaluated as a future domestic water source for both adult and child residents. . For purposes of this BHHRA, untreated surface water was used to assess risks from future domestic water uses, so the risks are considered hypothetical. . Risks were calculated for year-round exposure to surface water for the four transect stations within the Study Area and single point vertically integrated samples from Cathedral Park, Willamette Cove, and Swan Island Lagoon. . In addition, Study Area-wide risk was calculated by combining the data from all vertically integrated samples to estimate Study Area-wide exposure. . The results of~~

~~the risk evaluation for surface water as a hypothetical future domestic water source are presented in Tables 5-57 through 5-58 for adult residents, Tables 5-59 through 5-60 for child residents, and Tables 5-61 through 5-62 for combined child and adult residents.~~

~~5.12.3.4.1 Adult Resident~~

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~~The adult resident RME scenario for hypothetical future use of untreated surface water as a domestic water source results in cumulative risk exceedances of 1 x 10^{-6} at all 20 of the 20 exposure areas, and for Study Area-wide exposure (see Table 5-57). There is one exceedance of 1 x 10^{-4} cancer risk for the adult resident RME future hypothetical domestic water scenario, which occurs at RM 6.1 (cumulative risk is 3 x 10^{-4}, primarily due to benzo(a)pyrene in drinking water). Risks from untreated surface water exposure to both total and dissolved arsenic exceed 1 x 10^{-6} for all exposure areas. The adult resident RME scenario results in no HIs greater than 1.~~

~~Arsenic is a naturally occurring metal, and background concentrations in surface water may contribute to risk resulting from the hypothetical future use of untreated surface water as a domestic water source. Background concentrations for some chemicals in surface water were calculated using data collected from upstream of the Study Area, as described in Section 6 of the RI Report. The 95% percent UCL concentration of total arsenic in surface water upstream of the Study Area is 0.402 ug/l, and the 95th percentile value is 0.485 ug/l, which are both above the EPA tap water RSL for arsenic of 0.045 ug/l but below the EPA MCL of 10 ug/l. The 95% percent UCL/max EPCs for total arsenic for the hypothetical future use of untreated surface water for domestic use within the Study Area range from 0.32 to 0.60 ug/l, which include both maximum concentrations for an exposure area and 95% percent UCLs for an exposure area. EPCs at 17 out of 21 locations within the Study Area exceed 0.402 ug/l (the 95% percent UCL concentration of total arsenic in surface water upstream of the Study Area), and seven out of 21 of the EPCs exceed 0.485 ug/l (the 95th percentile value of total arsenic in surface water upstream of the Study Area). These concentrations are similar to the upstream arsenic concentration statistics. The 95% percent UCL concentration of total arsenic upstream of the Study Area (0.402 ug/l) results in a cancer risk of 7 x 10^{-6} for the adult resident exposure scenario.~~

~~The adult resident CT scenario for hypothetical use of untreated surface water as a future domestic water source results in cumulative risk exceedances of 1 x 10^{-6} at 17 of the 20 exposure areas, and for Study Area-wide exposure (see Table 5-58). There are no exceedances of 1 x 10^{-4} cancer risk for the adult resident CT future hypothetical domestic water scenario. The maximum cumulative cancer risk for the CT scenario is 3 x 10^{-5}, which occurs at RM 6.1. This exceedance is due to the hypothetical ingestion of untreated surface water containing benzo(a)pyrene. The adult resident CT scenario results in no HIs greater than 1.~~

~~5.12.3.4.2 Child Resident~~

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~~The child resident RME scenario for hypothetical future use of untreated surface water as a domestic water source results in cumulative risk exceedances of 1 x x 10^{-6} at all 20 of the 20 exposure areas, and for Study Area-wide exposure (see Table 5-59). . There is one exceedance of 1 x x 10^{-4} cancer risk for the child resident RME future hypothetical domestic water scenario, which occurs at RM 6.1 (cumulative risk is 7 x x 10^{-4}, primarily due to benzo(a)pyrene in drinking water). . The child resident RME scenario results in HIs greater than 1 at two locations: RM 2.9 (Multnomah Channel) and RM 8.5. . The HI at both of these locations is 2, due primarily to exposures to MCPP in drinking water. .~~

~~The child resident CT scenario for hypothetical use of surface water as a future domestic water source results in cumulative risk exceedances of 1 x x 10^{-6} at all 20 of the 20 exposure areas, and for Study Area-wide exposure (see Table 5-60). . There is one exceedance of 1 x x 10^{-4} cancer risk for the child resident CT future hypothetical domestic water scenario, which occurs at RM 6.1 (cumulative risk is 2 x x 10^{-4}, primarily due to benzo(a)pyrene in drinking water). . The child resident CT scenario results in no HIs greater than 1.~~

~~5.12.3.4.3 Combined Child and Adult Resident~~

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~~Cancer risks for a combined child and adult resident were calculated to incorporate early life exposures, per EPA (2005) and DEQ (2010) guidance. . The maximum cancer risk for the combined child and adult receptor is 9 x x 10^{-4}, occurring at RM 6.1, primarily from exposures to benzo(a)pyrene in drinking water. . Risks from RME and CT scenarios exceed 1 x x 10^{-6} for all exposure areas evaluated.~~

~~5.12.3.5 Summary of Surface Water Risk Characterization~~

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~~Direct contact with surface water resulted in cumulative cancer risks ranging from 8 x x 10^{-10} to 9 x x 10^{-4} across all scenarios, including hypothetical future use as a domestic water source. The only HIs that were greater than 1 were for hypothetical future use as a domestic water source by a child resident under the RME scenario. . The HI was 2 at Multnomah Channel and RM 8.5, due primarily to ingestion of MCPP in surface water. . Eight contaminants resulted in a cancer risk greater than 1 x x 10^{-6} or hazard quotient greater than 1 for at least one of the surface water scenarios, including: benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene, dibenzo(a,h)anthracene, indeno(1,2,3-cd)pyrene, MCPP, arsenic, hexavalent chromium, and total PAHs. . A summary of risks from exposure to surface water is provided in Table 5-63.~~

~~5.12.4 Groundwater Seep Risk Characterization Results~~

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~~Only one groundwater seep was identified in a transient or recreational use area where upland COIs were potentially discharging. . The seep identified is actually the potential groundwater discharge that could occur from Outfall 22B, which discharges~~

~~into a transient use area. . As a result, risks to transients from potential exposure to groundwater seeps were evaluated at that beach (07B024). .~~

~~5.12.4.1 Transients~~

~~Risks to transients from the groundwater seep were evaluated for direct contact scenarios. . There were multiple uncertainties associated with the exposure parameters for the direct exposure to groundwater seeps scenario. . To evaluate the risks from exposure to the groundwater seep without stormwater influence, outfall data from stormwater sampling events was excluded from the dataset. . The results of the risk evaluation for transient exposure to the groundwater seep are presented in Tables 5-64 through 5-65.~~

~~The transient RME and CT scenarios for the groundwater seep results in no exceedances of 1 x x~~ ~~10^{-6}~~ ~~cancer risk and no exceedances of an HI of 1. .~~

~~6.1.1.1 Summary of Groundwater Seep Risk Characterization~~

~~There were no cancer risk or noncancer hazard exceedances from exposure to the groundwater seep. . A summary of groundwater seep risks is provided in Table 5-66.~~

~~5.12.5 Fish Consumption Risk Characterization Results~~

~~Potential risks from fish consumption were estimated for fisher and tribal fisher scenarios. . There were multiple uncertainties associated with the fish consumption scenarios such as assumptions regarding fish consumption rates, tissue type and fish species consumed, EPCs, and the use of cooking and preparation methods[7]. . Uncertainties associated with this scenario are discussed further in Section 6.~~

~~5.12.5.1 Tribal Fishers~~

~~Risks to tribal fishers who consume fish caught within the Study Area were evaluated for a multi-species diet that includes salmon, lamprey, and sturgeon, in addition to resident fish species. . A single ingestion rate for the multi-species diet was used to evaluate risks to the tribal fish consumer. . Risks were evaluated using both 95% percent UCL/max and mean Study Area-wide tissue concentrations for both fillet and whole body tissue (see Section 3.4.5). . Risks were higher for whole body tissue than for fillet tissue; however, fillet tissue was not analyzed for PCB or dioxin/furan congeners in all resident species. . The results of the risk evaluation for adult tribal fish consumption are presented in Tables 5-67 through 5-70. . The results of the risk evaluation for child tribal fish consumption are presented in Tables 5-71 through 5-74, and the results of the risk evaluation for the combined child and adult tribal consumers of fish are presented in Tables 5-75 through 5-76.~~

~~[7] For the purposes of the risk calculations, reference to "uncooked" fish tissue is the same as not accounting for reductions in contaminant concentrations from cooking or other food preparation.~~

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~~5.12.5.1.1 Tribal Adult, Fish Consumption~~

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~~The risks ranged from a cumulative cancer risk of 2 x x 10^{-2} for the 95% percent UCL/max EPCs of whole body tissue to a cumulative cancer risk of 2 x x 10^{-3} for the mean EPCs of fillet tissue. . For all scenarios, estimated risks are above a 1 x x 10^{-4} cumulative cancer risk and are primarily due to PCBs and dioxins/furans. . Figure 5-8 shows the relative risk contribution of individual COPCs for both whole body and fillet tissue diets of an adult tribal consumer, and Figure 5-9 shows a comparison of total risk per tissue type.~~

~~The cumulative HIs ranged from 400 for the 95% percent UCL/max EPCs of whole body tissue to 50 for the mean EPCs of fillet tissue. . For the whole body tissue, 95% percent UCL/max EPC scenario, the PCB HQ is approximately 26 times higher than any other HQ. . The toxicity endpoint for PCBs is immunological and skin. . The immunological- and skin-specific HIs for tribal adult consumption are the highest endpoint-specific HIs, and exceed the next highest HI by a factor of 10. . Additional endpoints that exceed an HI of 1 for the tribal adult 95% percent UCL/max consumption scenario are reproduction, central nervous system (CNS), and blood.~~

~~The multi-species diet evaluated in this BHHRA included resident fish as well as salmon, sturgeon, and lamprey. . Because salmon, sturgeon, and lamprey spend time outside the Study Area, the risks from ingestion of salmon, sturgeon, and lamprey cannot be conclusively associated with sources within the Study Area. . However, resident fish accounted for approximately 95 percent of the cumulative risk in the whole body diet. Of the four resident fish species included in the multi-species diet, risks from ingestion of smallmouth bass and common carp were the primary contributors to the cumulative risk. .~~

~~5.12.5.1.2 Tribal Child, Fish Consumption~~

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~~The risks ranged from a cumulative cancer risk of 3 x x 10^{-3} for the 95% percent UCL/max EPCs of whole body tissue to a cumulative cancer risk of 4 x x 10^{-4} for the mean EPCs of fillet tissue. . For all scenarios, risks are above a 1 x x 10^{-4} cumulative cancer risk and are primarily due to PCBs and dioxins/furans.~~

~~The cumulative HIs ranged from 800 for the 95% percent UCL/max EPCs of whole body tissue to 100 for the mean EPCs of fillet tissue. . The PCB HQ for the whole body tissue diet is approximately 26 times higher than any other HQ. The immunological- and skin- specific HIs for tribal child consumption are the maximum endpoint-specific HIs, and exceed the next highest HI by a factor of 10. . Additional health endpoints that exceed an HI of one for the tribal child 95% percent UCL/max consumption scenario are reproduction, CNS, liver, and blood.~~

~~The multi-species diet evaluated in this BHHRA included resident fish as well as salmon, sturgeon, and lamprey. . Because salmon, sturgeon, and lamprey spend time outside the Study Area, the calculated risks from ingestion of salmon, sturgeon, and lamprey cannot be conclusively associated with sources within the Study Area. .~~

~~However, resident fish accounted for approximately 95 percent of the cumulative risk associated with this scenario.~~

~~5.12.5.1.3 Combined Tribal Child and Adult, Fish Consumption~~

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~~Cancer risks were calculated for the combined child and adult tribal fisher scenarios in order to incorporate early life exposures (EPA 2005, DEQ 2010). . Cumulative cancer risks from fish consumption for the combined child and adult tribal fisher ranged from 3 x x 10^{-3} (fillet tissue consumption, mean scenario) to 2 x x 10^{-2}, (whole body tissue consumption, 95% percent UCL/Max scenario) primarily due to ingestion of PCBs in tissue. . The results of the combined tribal child and adult cancer risks for consumption of fish tissue are presented in Tables 5-75 and 5-76.~~

~~5.12.5.1.4 Breastfeeding Infant of Tribal Adult Who Consumes Fish~~

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~~Risks and hazards to an infant consuming human milk of a tribal adult who consumes fish were calculated for bioaccumulative compounds, consistent with EPA (2005) and DEQ (2010) guidelines. . These risks are presented in Tables 5-77 and 5-78. . Cancer risks range from 2 x x 10^{-3} to 2 x x 10^{-2}, and noncancer hazards range from 1,000 to 9,000.~~

~~5.12.5.1.5 Summary of Risks from Tribal Consumption of Fish~~

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~~A summary of risks from tribal consumption of fish is provided in Table 5-79. . Both cancer risks and noncancer hazards exceed the target risk values of 1 x x 10^{-6} and 1, respectively, for all tribal receptors.~~

~~5.12.5.2 Non-tribal Fishers~~

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~~Risks for the non-tribal fish consumption scenarios were estimated for both single- and multi-species diets consisting only of resident fish species (smallmouth bass, black crappie, brown bullhead, and common carp). . Risks were estimated separately for each exposure area (based on species home range) and for Study Area-wide exposure. . Consumption of smallmouth bass was evaluated on a river mile basis, and consumption of common carp, brown bullhead, and black crappie was evaluated on a fishing zone basis (fishing zones were designated from RM 3-6 and from RM 6-9 for black crappie and brown bullhead, and from RM 3-6, RM 6-9, RM 0-4, RM 4-8, and RM 8-12 for common carp). . In addition to evaluating risks using mean and 95% percent UCL/max tissue concentrations for both whole body and fillet tissue, each fish consumption scenario was evaluated using three different ingestion rates for adult and child consumers. . The results of the risk evaluation for fish consumption by an adult are presented in Tables 5-80 through 5-119. . The results of the risk evaluation for fish consumption by a child are presented in Tables 5-120 through 5-159. . The results of the risk evaluation for fish consumption by a combined child and adult receptor are presented in Tables 5-160 through 5-169. In addition, Maps 5-4-1 through 5-7-3 show exposure areas with risk exceedances from 95% percent UCL/max EPCs for single species diets, at the 17.5 g/day, 73 g/day, and 142 g/day ingestion rates for adults.~~

~~5.12.5.2.1 Adult, Fish Consumption~~

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~~Risks to adult fish consumers were evaluated for ingestion rates of 142 g/day, 73 g/day, and 17.5 g/day. . These rates correspond to approximately 19 meals per month, 10 meals per month, and two meals per month, based on an 8-ounce serving size, every month of the year exclusively of resident fish caught within the Study Area.~~

~~The highest risk for all adult consumer scenarios was equal to a cumulative cancer risk of 6 x x 10^-2^. . This was for the scenario based on the 95% percent UCL/max EPC, 142 g/day ingestion rate, and a fish diet comprised solely of whole-body common carp. . The lowest risk was equal to a cumulative cancer risk of 7 x x 10^-6^ for the 95% percent UCL/max and mean EPCs, 17.5 g/day ingestion rate, and a fish diet comprised solely of black crappie fillet tissue. . For all tissue consumption scenarios, PCBs are the primary contributor to cumulative cancer risks. . The highest cumulative HI from fish tissue ranged from 3,000 for the 95% percent UCL/max EPC, 142 g/day ingestion rate, common carp fillet tissue scenario to 0.5 for the mean EPC, 17.5 g/day ingestion rate, black crappie fillet tissue-only scenario. . For the 95% percent UCL/max EPC, multi-species, whole body tissue scenario, the PCB HQ is approximately 30 times higher than the HQ for any other chemical. . In general, the immunological-specific HIs for adult consumption scenarios are the highest of all endpoint-specific HIs, and exceed the next highest HIs by a factor of 10 to 100. . Additional health endpoints that exceed an HI of 1 for the 95% percent UCL/max EPCs at the 17.5 g/day ingestion rate are reproduction, CNS, liver, skin, and blood.~~

~~Figures 5-10 through 5-17 show a summary of risk results for adult consumption of tissue for single species diets. . These figures illustrate the relative contribution of individual COPCs to total risk for both whole body and fillet tissue consumption, per river mile, per fishing area, and per species. .~~

~~In general, risks from consuming whole body tissue were greater than risks from consuming fillet tissue; however, fillet tissue was not analyzed for PCB or dioxin/furan congeners in black crappie or brown bullhead, and therefore PCB TEQ and dioxin/furan TEQ risks could be not evaluated in fillet tissue for those species. . Smallmouth bass and common carp diet scenarios generally resulted in higher risks than the other diets evaluated. . Black crappie diet scenarios generally resulted in the lowest risks of the diets evaluated. .~~

~~5.12.5.2.2 Child, Fish Consumption~~

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~~Risks to child consumers were evaluated for 60 g/day, 31 g/day, and 7 g/day ingestion rates. . The risks for all child consumer scenarios ranged from a cumulative cancer risk of 2 x x 10^-2^ for the 95% percent UCL/max EPC, 60 g/day ingestion rate, common carp whole body tissue-only scenario to a cumulative cancer risk of 3 x x 10^-6^ for the mean EPC, 7 g/day ingestion rate, black crappie fillet tissue-only scenario. . For all tissue consumption scenarios, PCBs are the primary contributor to cumulative cancer risks. .~~

~~The highest endpoint-specific HIs ranged from 5,000 for the 95% percent UCL/max EPC, 60 g/day ingestion rate, common carp whole body tissue-only scenario to 0.9 for the mean EPC, 7 g/day ingestion rate scenario for black crappie fillet tissue-only scenario. . For the 95% percent UCL/max EPC, multi-species, whole body tissue diet scenario, the PCB HQ is approximately 30 times higher than the HQ for any other chemical. . In general, the immunological-specific HIs for child consumption scenarios exceed the next highest HIs by a factor of approximately 10. . Additional health endpoints that exceed an HI of 1 for the child 95% percent UCL/max consumption scenarios at the 31 g/day ingestion rate are reproduction, CNS, liver, skin, and blood.~~

~~In general, risks from whole body tissue were greater than risks from fillet tissue. . Smallmouth bass and common carp diet scenarios generally resulted in higher risks than the other diets evaluated. . Black crappie diet scenarios generally resulted in the lowest risks of the diets evaluated. .~~

~~5.12.5.2.3 Combined Child and Adult, Fish Consumption~~

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~~Cancer risks were calculated for a combined child and adult consumer of fish, to account for early life exposures, for all fish consumption scenarios evaluated in this BHHRA. . Results for the evaluation of combined child and adult cancer risks from fish consumption are presented in Tables 5-160 through 5-169. . Cancer risks for the combined child and adult consumer of fish are generally the same order of magnitude as adult-only risks. . The highest cumulative cancer risk for the combined child and adult consumer is 7 x x 10^{-2}, which occurs at the child ingestion rate of 60 g/day and the adult ingestion rate of 142 g/day, due to consumption of whole body carp from the fishing zone covering RM 4 through RM 8.~~

~~5.12.5.2.4 Breastfeeding Infant of Adult Who Consumes Fish~~

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~~Risk and hazards to infants consuming human milk from adults consuming fish collected from the Study Area were assessed for bioaccumulative compounds for all adult fish consumption scenarios, in accordance with EPA (2005) and DEQ (2010) guidance. . Cancer risks to infants were calculated by applying an IRAF to the combined child and adult cancer risk from fish consumption. . Noncancer hazards were calculated by applying an IRAF to the adult HQ for each fish consumption scenario. . Results of the risk and hazard calculations for breastfeeding infants of adult consumers of fish are provided in Tables 5-170 through 5-179. . The highest cancer risk to a breastfeeding infant of an adult consumer of fish is 7 x x 10^{-2}, due primarily to PCBs in breastmilk. . The highest noncancer hazard is 60,000, also due primarily to PCBs in breastmilk.~~

~~5.2.5.3 Consideration of Regional Tissue Concentrations~~

~~PCBs and dioxins/furans have been detected in fish tissue collected in the Willamette and Columbia Rivers, outside of the Study Area. . In the Columbia River Basin Fish Contaminant Survey, the basin-wide average concentrations of total PCBs in resident fish ranged from 0.032 to 0.173 parts per million (ppm) for whole body samples and~~

~~from 0.033 to 0.190 ppm for fillet with skin samples (EPA 2002c). In the Middle Willamette River (RM 26.5 to 72), the average concentrations of total PCBs in resident fish ranged from 0.086 to 0.146 ppm for whole body samples and from 0.026 to 0.071 ppm for fillet with skin samples (EVS 2000). These concentrations are lower than the concentrations detected in the Study Area where average concentrations ranged from 0.16 to 2.8 ppm in whole body samples and from 0.17 to 2.5 ppm in fillet with skin samples (for PCBs as total congeners). The fish species included in the studies were different than those collected within the Study Area, so the concentrations may not be directly comparable. Sources contributing to the PCBs and dioxins/furans detected in fish collected outside of the Study Area are unknown and may not be relevant to the Study Area.~~

~~In addition, the LWG collected upstream fish tissue samples at RM 20 and 28 during Round 1. The data for the upstream fish tissue samples are described in further detail in Section 5.5 of the RI Report. While there are a limited number of samples and species in the upstream fish tissue dataset, the results from the upstream fish tissue are consistent with the results from the Columbia and mid-Willamette River studies.~~

~~The EPA established a target fish tissue concentration of 0.0015 ppm for PCBs to allow a monthly fish consumption rate of more than 16 meals per month (EPA 2000c). The highest fish ingestion rates used in this BHHRA, 142 g/day for adult fishers and 175 g/day for adult tribal fishers, equate to over 19 and 23 meals per month, respectively, assuming an eight-ounce meal size.~~

~~The target fish tissue concentration established by EPA is based on a target cancer risk level of 1 x 10^{-6}. The regional PCB concentrations detected in resident fish from the Willamette and Columbia Rivers are approximately 20 to 100 times higher than the EPA target fish tissue concentration. These concentrations from outside of the Study Area are equivalent to cancer risks ranging from 2 x 10^{-5} to 1 x 10^{-4} relative to the EPA target fish tissue concentration, indicating that regional concentrations of PCBs exceed the lowest target cancer risk level of 1 x 10^{-6} for fish consumption rates higher than 16 meals per month. For noncancer endpoints, the EPA established a target tissue concentration is 0.0059 ppm. Concentrations detected in resident fish from the Willamette and Columbia Rivers are up to 30 times higher than this target tissue concentration. Regional efforts are underway to reduce concentrations in fish tissue.~~

~~5.2.5.4 Summary of Fish Consumption Risk Characterization~~

~~Consumption of individual species by the fisher resulted in cumulative cancer risks ranging from 7 x 10^{-6} to 6 x 10^{-2} for the adult consumer and from 3 x 10^{-6} to 2 x 10^{-2} for the child consumer. The maximum endpoint-specific hazard index (HI) for both adult and child fish consumption scenarios was for the immunological endpoint, primarily due to consumption of PCBs in tissue. The highest HI for the immunological endpoint occurs from child consumption of whole body common carp~~

~~tissue from river miles (RM) 4-8. .The range of HIs for the immunological endpoint across all single-species exposure scenarios evaluated for non-tribal consumers is from 0.9 to 3,000 for the adult fish consumer and from 0.7 to 5,000 for the child fish consumer.~~

~~Fish consumption risks were also evaluated for adult and child tribal fishers based on the 95th percentile ingestion rate from the CRITFC Consumption Study (1994). The tribal fish consumption risks assumed a multi-species diet consisting of resident fish species (common carp, black crappie, brown bullhead, and smallmouth bass) as well as sturgeon, lamprey, and salmon. .Risks from the tribal fish diet were based on consumption of either whole body or fillet with skin tissue. .It was assumed that all fish consumed were caught within the Study Area. .Consumption of fish by the tribal fisher resulted in cumulative cancer risks ranging from 2 x x 10^{-3} to 2 x x 10^{-2} for the tribal adult fisher and from 4 x x 10^{-4} to 3 x x 10^{-3} for the tribal child consumer. .The maximum endpoint-specific HIs for both the tribal adult and tribal child fishers were for the immunological endpoint, primarily due to consumption of PCBs in fish tissue. .The range of immunological HIs for all tribal fisher fish consumption scenarios was from 50 to 400 for the tribal adult and from 100 to 800 for the tribal child.~~

~~Twenty-four contaminants resulted in a cancer risk greater than 1 x x 10^{-6} or hazard quotient greater than 1 for at least one of the fish consumption scenarios evaluated in the draft BHHRA. The contaminants identified as posing potentially unacceptable risks were: PCBs, dioxins, six metals (antimony, arsenic, lead, mercury, selenium, and zinc), bis 2-ethylhexyl phthalate (BEHP), PAHs, hexachlorobenzene, and eleven pesticides (aldrin, dieldrin, heptachlor epoxide, total chlordane, total DDD, total DDE, total DDT, alpha-, beta, and gamma-hexachlorocyclohexane, and heptachlor). . Of these, PCBs resulted in the highest cancer risks and hazard quotients.~~

~~A summary of risks from fish consumption is provided in Tables 5-180 and 5-181.~~

~~5.12.6 Shellfish Consumption Risk Characterization Results~~

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~~5.12.6.1 Adult, Shellfish Consumption~~

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~~Potential risks from shellfish consumption were estimated for the adult fisher scenarios. .Risks to adult shellfish consumers were evaluated for clam and crayfish diets. .For crayfish, risks were evaluated for each sample station and for Study Area-wide exposure. .For clam, risks were evaluated on a river-mile basis and for Study Area-wide exposure separately for depurated and undepurated tissue, as agreed upon with EPA. .Risks were estimated for an 18 g/day ingestion rate, which equates to approximately two and a half 8-ounce meals per month, and for a 3.3 g/day ingestion rate, which is just less than an 8-ounce meal every 2 months. .Risks were calculated using both the 95% percent UCL/max and mean tissue concentrations of shellfish tissue. .The results of the risk evaluation for shellfish consumption are presented in~~

~~Tables 5-182 to 5-193. . Cumulative risk exceedances for shellfish scenarios are summarized by exposure point in Maps 5-8-1 through 5-8-4. .~~

~~Estimated risks from shellfish consumption within the Study Area ranged from a high cumulative cancer risk of 7 x x 10^{-4}, which was for the 95% percent UCL/max EPCs, 18 g/day ingestion rate undepurated clam tissue scenario, to a cumulative cancer risk of 9 x x 10^{-7}, which was for the mean EPC, 3.3 g/day ingestion rate crayfish tissue scenario. . Estimated risks from shellfish consumption in areas assessed outside of the Study Area ranged from 2 x x 10^{-6} to 8 x x 10^{-5}. Clam samples were not all analyzed for the same chemicals, and the uncertainties associated with the resulting risks are discussed in Section 6. . Study Area-wide risks from ingestion of undepurated clam tissue are two to three times higher than Study Area-wide risks from ingestion of depurated clam tissue, as shown in Table 5-182 and Table 5-183. Depurated clam tissue samples were collected from five locations at the northern and southern edges of the Study Area, while undepurated clam tissue samples were collected from 22 locations throughout the Study Area. . For all high ingestion rate scenarios, risks are above a 1 x x 10^{-6} cumulative cancer risk and are primarily due to PCBs.~~

~~Figures 5-18 through 5-21 show the relative contribution of individual COPCs to total risks from clam and crayfish consumption, as well as a summary of total risks per exposure point for the different ingestion rates.~~

~~The cumulative HIs from shellfish consumption ranged from 40 for the 95% percent UCL/max EPCs, 18 g/day ingestion rate, undepurated clam tissue scenario to 0.06 for the mean EPCs, 3.3 g/day ingestion rate, crayfish tissue scenario. . Noncancer hazards above an HI of 1 are primarily due to PCBs. Study Area-wide HIs from ingestion of undepurated clam tissue are one to two times higher than Study Area-wide risks from ingestion of depurated clam tissue. . These results are shown in Table 5-182 and Table 5-183.~~

~~5.12.6.2 Breastfeeding Infant of Adult Who Consumes Shellfish~~

~~Risk and hazards to infants consuming human milk from adults consuming shellfish were assessed for bioaccumulative compounds for all adult shellfish consumption scenarios, in accordance with EPA (2005) and DEQ (2010) guidance. . Cancer risks and noncancer hazards to infants were calculated by applying an IRAF to the adult cancer risk and noncancer results from shellfish consumption, as shown in Tables 5-194 through 5-197. . The highest cancer risk to a breastfeeding infant of an adult consumer of shellfish is 7 x x 10^{-4}, from human milk consumption of an adult who consumed undepurated clam tissue at the 18 g/day ingestion rate. . The risk is primarily from PCBs in breastmilk. . The highest cumulative hazard quotient from bioaccumulative chemicals is 800 due primarily to PCBs in breastmilk.~~

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~~6.1.1.1 Summary of Risks from Consumption of Shellfish~~

~~A summary of risks from consumption of Shellfish is provided in Table 5-198 by receptor and analyte. Cancer risks and noncancer hazards exceed the targets of 1 x x 10^-6 and 1, respectively, for all scenarios evaluated.~~

~~5.12.7 Evaluation of Cumulative and Overlapping Scenarios~~

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~~As shown in the conceptual site model (Figure 3-1), multiple exposure scenarios may exist for a given population. For example, recreational beach users are potentially exposed to both beach sediment and surface water. The risks for each of the exposure scenarios that are considered potentially complete and significant for a given population were summed to estimate the cumulative risks for that population. The cumulative risks are presented in Table 5-199 for 95% percent UCL/max exposures, and in Table 5-200 for mean exposures. Additionally, cumulative risks for divers exposed to both in-water sediment and surface water are presented on a ½-river mile basis, per side of river, in Table 5-201 for RME exposures and Table 5-202 for CT exposures.~~

~~As discussed in Section 3, certain individuals may be exposed to COPCs within the Study Area through multiple exposure scenarios; for example, a recreational beach user might also be a fisher. This BHHRA quantitatively estimated risks for the individual exposure scenarios. Due to multiple exposure locations over different scales for both RME and CT scenarios, as well as ranges of ingestion rates and multiple diets for fish consumption, there are numerous potential combinations of overlapping scenarios. As a result, this BHHRA did not quantitatively evaluate all possible overlapping scenarios. However, risks from fish consumption are generally at least an order of magnitude higher than risks from other exposure scenarios, so if an individual consumes fish, the contribution from other exposure scenarios is not likely to contribute significantly to the overall risks for that individual.~~

~~5.12.8 Risk Characterization of Lead~~

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~~A great deal of information on the health effects of lead has been obtained through decades of medical observation and scientific research. By comparison to most other environmental toxicants, the degree of uncertainty about the health effects of lead is quite low. The adverse health outcomes, which include neurotoxic and developmental effects, may occur at exposures so low that they may be considered to have no threshold. EPA views it to be inappropriate to develop noncarcinogenic "safe" exposure levels (RfDs) for lead. Because age, health, nutritional state, body burden, and exposure duration influence the absorption, release, and excretion of lead, EPA has not established standard toxicity endpoints values for lead based on an external dose.. Instead, the concentration of lead in the blood is used as an index of the total dose of lead, regardless of the route of exposure (EPA 1994). As a result, blood lead levels, rather than intakes, are used to evaluate potential risks associated with exposure to lead. The Centers for Disease Control (CDC) has identified a~~

~~blood lead level of 10 micrograms per deciliter (µg/dl) as the level of concern above which significant health risks may occur (CDC 1991). . An acceptable risk for lead exposure to lead typically equates to a predicted probability of no more than 5 percent greater than the 10 µg/dl level (EPA 1998b). .~~

~~Lead was identified as a COPC for in-water sediment, fish and shellfish. . The following discusses the evaluation of risks from lead for each of those media.~~

~~5.12.8.1 In-Water sediment~~

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~~Lead was identified as a COPC for in-water sediment because the maximum detected concentration exceeds the RSL for industrial soil of 800 mg/kg. . The RSL was developed to be protective of the fetus of a pregnant woman exposed to lead. . The only receptors for in-water sediment exposures are adults. . Therefore, the fetus of a pregnant in-water worker or fisher is the most sensitive scenario for exposure to lead in in-water sediment, and the RSL is protective of that scenario. . While maximum detected concentrations were used in identifying COPCs, EPCs were used to calculate risks. . The maximum EPC for one of the in-water sediment exposure areas (2,200 mg/kg) is greater than the RSL. The adult lead model (ALM, Version 5/19/05, EPA 2003c) was used to estimate the probability of exceeding a target blood level for lead of 10 µg/dl from exposure to in-water sediment. Exposure parameters from Table 3-27 were used to develop site-specific ALM input parameters. . For scenarios modeling exposure to in-water sediment, the exposure factors from Table 3-27 were adjusted with the assumption of a 25% percent sediment contact frequency. . For ALM parameters without site-specific values, the model defaults for the West Region from Phases 1 and 2 of the National Health and Nutrition Evaluation Survey (NHANES III) (EPA 2002e) were used. . The site-specific ALM blood lead concentration estimates for receptors potentially exposed to in-water sediment within the Study Area are presented in Tables F5-1 and F5-2 of Attachment F5.~~

~~Using the maximum EPC of 2,200 mg/kg, the maximum estimated probability of exceeding a fetal blood lead level of 10 µg/dL for any in-water sediment exposure scenario is one percent, which is for the RME in-water worker and RME high-frequency fisher scenarios. . Because the maximum EPC for lead results in a probability of exceeding protective blood lead levels in the fetus of a pregnant woman that is less than 5 percent, lead is not considered a chemical potentially posing unacceptable risks for in-water sediment. . All other EPCs for lead were below the RSL. . The uncertainty associated with the evaluation of lead is discussed further in Section 6.~~

~~5.12.8.2 Fish~~

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~~Lead was identified as a COPC for fish consumption because it was detected in fish tissue. . The Columbia River Basin Fish Contaminant Survey (EPA 2002e) determined fish tissue concentrations for lead that are unlikely to result in blood lead levels exceeding 10 µg/dl for the fetus of a pregnant adult, and for children. . These~~

~~concentrations were developed using the ALM (EPA 2003c) and the Integrated Exposure Uptake Biokinetic Model for Lead in Children (IEUBK, EPA 2007d), in combination with the fish ingestion rates from the CRITFC Fish Consumption Survey (CRITFC 1994). The concentrations of concern were developed using health protective exposure assumptions and were considered unlikely to underestimate risks from fish consumption.~~

~~*Adults*~~
~~The following equations from the ALM were used in the Columbia River Basin Fish Contaminant Survey (EPA 2002c) to develop tissue concentrations to be protective of fetuses of tribal adults:~~
~~$PbB_a = PbB_o + BKSF * (PbF * IR_F * AF_F * EF_F)/AT$~~
~~$PbBf = PbB_a * 0.9$~~

~~Probability that fetal blood lead is less than 10 µg/dl using the z-value where:~~
~~$p' = \Phi z$ [(ln(PbBf)-ln(10)) /ln(GSD)]~~

~~Where:~~
~~PbB_a = Central tendency of adult blood lead level~~
~~PbB_o = Adult baseline blood lead level~~
~~PbBf = Fetal blood lead level~~
~~GSD = Geometric standard deviation~~
~~BKSF = Biokinetic slope factor~~
~~PbF = Lead fish tissue concentration~~
~~IR_F = Fish tissue ingestion rate~~
~~AF_F = Absolute gastrointestinal ingestion factor for ingested lead in tissue~~
~~EF_F = Exposure frequency of fish ingestion~~
~~AT = Averaging time~~

~~The EPA (2003c) ALM approach was used to determine protective fish tissue concentrations for the fetuses of both adult fishers and adult tribal fishers in the Study Area, using updated default ALM assumptions for the West Region, which are based on current EPA guidance (EPA 2003c). Differences in default parameter values from the EPA (2003c) application of the ALM to the ALM application for this BHHRA include a change in PbB_o from 2.2 µg/dl to 1.4 µg/dl, and a change in AF_F from 0.1 to 0.12.~~

~~The evaluation of risks from lead is based on geometric mean levels and associated probabilities, so median values are generally used as inputs to the equations. The mean estimate of national per capita fish consumption of 7.5 g/day was used as the consumption rate for adults (EPA 2000b). The median fish ingestion rate for tribal fishers is 39.2 g/day, as stated in the CRITFC Fish Consumption Survey (CRITFC 1994) and used by the EPA (2002c) in calculations of protective lead tissue concentrations. The ALM inputs and~~

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~~**results for estimating protective lead tissue concentrations for fetuses of adult fishers and adult tribal fishers consuming fish in the Study Area are provided in Table F5-**~~

~~**3 of Attachment F5.**~~

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~~Using the above equations, the ALM predicts that fetal blood lead levels will exceed 10 µg/dl less than 5 percent of the time for adult fishers at a lead fish tissue concentration of 5.25 mg/kg. The maximum fish tissue EPC for lead in the Study Area is 1,100 mg/kg, detected in a smallmouth bass whole body tissue sample. This is above the protective concentration of 5.25 mg/kg. However, this maximum EPC is orders of magnitude greater than all other resident fish EPCs and may be attributable to lead in the gut of the fish due to the ingestion of a metallic object (e.g., sinkers) (Integral 2008). There are no other resident fish tissue EPCs which exceed a protective lead concentration of 5.25 mg/kg. Therefore, while lead is considered a preliminary chemical potentially posing unacceptable risks for fish ingestion by an adult fisher, the uncertainties associated with the maximum detected concentration and evaluations of lead are discussed further in Section 6.~~.

~~The protective lead tissue concentration for fetuses of tribal adults, using the above methods, is 1.01 mg/kg. The maximum fish tissue lead EPC for an adult tribal fisher is 23 mg/kg. However, the tribal fisher tissue ingestion scenario is for a multi-species diet consisting of both resident and anadromous species. There are no detected concentrations in anadromous species exceeding 1.01 mg/kg. Over 99% percent of the lead in the maximum lead EPC for tribal fishers is attributable to the Study Area-wide EPC for lead in smallmouth bass, which is influenced by the maximum EPC mentioned above for adult fishers. Therefore, while lead is considered a preliminary chemical potentially posing unacceptable risks for fish ingestion by an adult tribal fisher, the uncertainties associated with the maximum detected concentration and evaluations of lead are discussed further in Section 6.~~.

~~*Children*~~
~~The EPA (2002c) used the IEUBK model in the Columbia River Basin Fish Contaminant Survey to determine risks from ingestion of lead in tissue in tribal children. The same IEUBK methodology was applied to assess risks to children from ingestion of lead in fish tissue for this BHHRA.~~

~~To assess risks to children from ingestion of lead in fish tissue, a protective tissue concentration of lead in fish tissue was calculated using the IEUBK model with all exposure parameters set to default levels and with the addition of a fish ingestion rate based on the child consumption scenario for this BHHRA. The default exposure parameters for the IEUBK model, provided as Table F5-4, are the same model parameters used by the EPA (2002c) because site-specific values for soil lead concentration, house dust lead concentration, lead concentration in air and drinking water are not readily available. The ratio of child to adult consumption rates of 0.42, described in Section 3.5.1.5, was applied to the consumption rate for adults of 7.5~~

~~g/day to obtain a consumption rate for children of 3.15 g/day.~~ . ~~In accordance with the methodology used by the EPA (2002c), fish ingestion was specified in the IEUBK model as the percentage of meat in diet consisting of locally caught fish and the lead concentrations in the fish.~~ . ~~The protective fish tissue concentration for a child consumer, using the above method, is 2.6 mg/kg lead in fish tissue.~~ . ~~The protective fish tissue concentration of 2.6 mg/kg is the fish tissue concentration resulting in predicted geometric blood lead level of 4.6 µg/dl and the probability of achieving a blood lead level greater than 10 µg/dl is no more than 5 percent.~~ .

~~The Columbia River Basin Fish Contaminant Survey (EPA 2002c) determined that 0.5 mg/kg is a protective tissue concentration for tribal children consuming tissue at a rate of 16.2 g/day, which is the 65th percentile consumption rate from their survey.~~ . ~~Within the Portland Harbor Study Area, the maximum lead tissue EPC for the tribal child consumption scenario is 23 mg/kg, which is greater than the estimated protective concentration.~~ . ~~Over 99%~~ percent ~~of this concentration is attributable to the contribution from the Study Area-wide smallmouth bass EPC.~~ . ~~There are no anadromous species with detected lead concentrations exceeding 0.5 mg/kg.~~ . ~~Therefore, while lead is considered a preliminary chemical potentially posing unacceptable risks for fish tissue for a tribal child consumer, the uncertainties associated with the maximum detected concentration and evaluations of lead are discussed further in Section 6.~~ .

~~5.12.8.3 Shellfish~~

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~~Lead was identified as a COPC for shellfish consumption because it was detected in shellfish tissue.~~ . ~~Shellfish consumption was only evaluated for adult scenarios.~~ . ~~Therefore, the tissue concentration of concern for fetuses is the only tissue concentration relevant for shellfish consumption.~~ . ~~The CRITFC approach to assessing risks from lead using the ALM was applied to the shellfish ingestion scenario for the site.~~ . ~~Using the ALM equations applied to adult fishers in the previous section, the mean shellfish ingestion rate of 3.3 g/day, and the maximum shellfish exposure point concentration of 1,320 µg/kg, the ALM predicts that fetal blood lead levels will exceed 10 µg/dl less than 5 percent of the time.~~ . ~~Therefore, lead is not considered a chemical potentially posing unacceptable risks for shellfish consumption. The ALM parameter values and results used to assess risk from adult exposure to lead via ingestion of shellfish are shown in Attachment F5.~~

~~5.13~~5.3 CUMULATIVE RISK ESTIMATES~~SUMMARY OF RISK CHARACTERIZATION~~

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~~Cancer risk and noncancer hazard from site-related contamination was characterized based on current and potential future uses at Portland Harbor, and a large number of different exposures scenarios were evaluated. Exposure to bioaccumulative contaminants (PCBs, dioxins/furans, and organochlorine pesticides, primarily DDE/DDD/DDT) via consumption of resident fish consistently poses the greatest~~

~~potential for human exposure to in-water contamination. The ranges of estimated potential risks resulting from the different exposure scenarios evaluated in this BHHRA are summarized in Table 5-203. . The ranges included in Table 5-203 for different scenarios reflect differences in CT vs. RME scenarios, differences in tissue EPCs (mean vs. 95% percent UCL/max), level of fish consumption (17.5 g/day [EPA 2002b], 73 g/day [Adolfson 1996], and 142 g/day [EPA 2002b]), location of sediment (for beach scenarios), tissue type (whole body vs. fillet or depurated vs. undepurated), and species of fish consumed. . There were multiple uncertainties associated with the different scenarios such as the spatial scale of EPCs, sediment and surface water exposure parameters, tissue consumption rates, tissue type and fish and shellfish species consumed, fish and shellfish cooking and preparation methods, and contributions from background. .~~

~~In general, the risks from fish consumption are higher than any of the other exposure scenarios evaluated in this BHHRA. . These risks can be summarized as follows:~~

- ~~The range of cumulative risks from all fish consumption scenarios is 3 x x 10^{-6} to 7 x x 10^{-2}, and the cumulative HIs range from 0.5 to 5,000. . The highest HI for a breastfeeding infant of a fish consumer is 60,000. .~~

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- ~~Cumulative cancer risks from consumption of shellfish range from 9 x x 10^{-7} to 7 x x 10^{-4}, and the cumulative HIs range from 0.06 to 40. . The highest HI for a breastfeeding infant of a shellfish consumer is 800. .~~

- ~~For beach sediment, cumulative cancer risks range from 8 x x 10^{-9} to 9 x x 10^{-5}, and the cumulative HIs range from 5 x x 10^{-4} to 1.~~

- ~~For in-water sediment, cumulative cancer risks range from 3 x x 10^{-9} to 3 x x 10^{-4}, and the cumulative HIs range from 6 x x 10^{-5} to 3. . The highest HI for a breastfeeding infant of an in-water sediment receptor is 5 (for the tribal fisher).~~

- ~~For direct contact to surface water, cumulative cancer risks range from 8 x x 10^{-10} to 9 x x 10^{-4}, and the cumulative HIs range from 1 x x 10^{-5} to 2. .~~

- ~~For groundwater seeps, cumulative cancer risks range from 4 x x 10^{-10} to 3 x x 10^{-9}, and the cumulative HIs range from 1 x x 10^{-3} to 6 x x 10^{-3}. .~~

~~Chemicals that resulted in a cancer risk greater than 1 x x 10^{-6} or an HQ greater than 1 under any of the exposure scenarios for any of the exposure point concentrations evaluated in this BHHRA are presented in Table 5-204.~~ Cumulative risk and hazard estimates were calculated for those populations where concurrent exposure to more than one media was assumed to ~~occur~~be plausible. Recreational/subsistence and tribal fishers were further evaluated on the basis of whether they were assumed to fish predominately from the shore or from a boat. ~~Media~~Populations for which concurrent exposure to more than one media was considered for ~~each populated~~ are as follows:~~:~~

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- Transients: Beach sediment, in-water sediment, surface water
- Divers: In-water sediment, surface water
- Recreational beach users: Beach sediment, surface water
- Recreational fishers (beach): Beach sediment, fish tissue (fillet or whole body)
- Recreational fishers (boat): In-water sediment, fish tissue (fillet or whole body)
- Subsistence fishers (beach): Beach sediment, fish tissue (fillet or whole body), shellfish tissue
- Subsistence fishers (boat): In-water sediment, fish tissue (fillet or whole body), shellfish tissue
- Tribal fishers (beach): Beach sediment, fish tissue (fillet and whole body)
- Tribal fishers (boat): In-water sediment, fish tissue (fillet and whole body)

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Cumulative risk estimates are generally presented for each one-half river mile per side of the river, and the risk estimates for specific media appropriate to each one-half mile segment were used to calculate the total risk or hazard. For example, cumulative risks for subsistence fishers who fish from a boat and consume smallmouth bass would include the risks associated with exposure to in-water sediment at the specific half-mile, shellfish collected within same half-mile and side-of-river specific segment, and smallmouth bass from the larger river mile assessment. The results of the cumulative risk estimates are presented in Table 5-xxx through 5-xxx. Chemicals that resulted in a cancer risk greater than 1 x 10^{-6} or an HQ greater than 1 under any of the exposure scenarios for any of the exposure point concentrations evaluated in this BHHRA are presented in Table 5-~~204~~xxx.~~Risk estimates for each media were summed f~~

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~~SUMMARY OF RISK CHARACTERIZATION~~

~~Cancer risk and noncancer hazard from site-related contamination was characterized based on current and potential future uses at Portland Harbor, and a large number of different exposures scenarios were evaluated. Exposure to bioaccumulative contaminants (PCBs, dioxins/furans, and organochlorine pesticides, primarily DDE/DDD/DDT) via consumption of resident fish consistently poses the greatest potential for human exposure to in-water contamination. In general, the risks associated with consumption of resident fish are greater by an order of magnitude or more than risks associated with exposure to sediment or surface water. The greatest non-cancer hazard estimates are associated with bioaccumulation through the food~~

~~chain and exposure to infants via breastfeeding. Because the smallest scale over which fish consumption was evaluated was per river mile, the resolution of cumulative risks on a smaller scale is not informative. The highest relative cumulative risk or hazard estimates are at RM 2, RM 4, RM 7, Swan Island Lagoon, and RM 11. However, assuming exposure to sediment alone, areas posing the greatest risk are RM 6W, RM 7W, RM 8.5W, and RM 11E, shellfish consumption alone poses the greatest risks at RM 4E, RM 5W, RM 6W, and RM 6E.~~

~~Chemicals that resulted in a cancer risk greater than 1 x 10^{-6} or an HQ greater than 1 under any of the exposure scenarios for any of the exposure point concentrations evaluated in this BHHRA are presented in Table 5-204.~~

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5.4 SUMMARY OF RISK CHARACTERIZATION

Cancer risk and noncancer hazard from site-related contamination was characterized based on current and potential future uses at Portland Harbor, and a large number of different exposures scenarios were evaluated. Exposure to bioaccumulative contaminants (PCBs, dioxins/furans, and organochlorine pesticides, primarily ~~DDE/DDD/DDT)~~DDx compounds, via consumption of resident fish consistently poses the greatest potential for human exposure to in-water contamination. In general, the risks associated with consumption of resident fish are greater by an order of magnitude or more than risks associated with exposure to sediment or surface water. The greatest non-cancer hazard estimates are associated with bioaccumulation through the food chain and exposure to infants via breastfeeding. Because the smallest scale over which fish consumption was evaluated was per river mile, the resolution of cumulative risks on a smaller scale is not informative. The highest relative cumulative risk or hazard estimates are at RM 2, RM 4, RM 7, Swan Island Lagoon, and RM 11. However, assuming exposure to sediment alone, areas posing the greatest risk are RM 6W, RM 7W, RM 8.5W, and RM 11E, shellfish consumption alone poses the greatest risks at RM 4E, RM 5W, RM 6W, and RM 6E.

The results of the BHHRA will be used to derive risk-based PRGs and AOPCs for the FS, as well as to develop risk management recommendations for the Site. In addition, the BHHRA may be consulted by risk managers as they deliberate practical risk management objectives during the course of the FS.

~~7.0~~6.0 UNCERTAINTY ANALYSIS

The presence of uncertainty is inherent in the risk assessment process~~Uncertainty is associated with every step of a risk assessment~~, from the sampling and analysis of chemicals in environmental media to the assessment of exposure and toxicity, and ~~the~~ risk characterization~~.~~. EPA policy calls for numerical risk estimates to always be accompanied by descriptive information regarding the uncertainties of each step in the risk assessment to ensure an objective and balanced characterization of the true risks and hazards~~.~~. ~~In general, the approach and methodologies used in a risk assessment are designed to err on the side of conservatism, i.e., protection of health. In a deterministic risk assessment, conservative assumptions can compound to result in an estimate of risk that is at the upper end of the probable risk range.~~

The te~~rm RM~~rm “uncertainty” is often used in risk assessment to describe what are, in reality, two conceptually different terms:– uncertainty and variability~~.~~. Uncertainty can be described as the lack of a precise knowledge resulting in a fundamental data gap~~.~~. Variability describes the natural heterogeneity of a population~~.~~. Uncertainty can sometimes be reduced or eliminated through further measurements or study~~.~~. By contrast, variability is inherent in what is being observed~~.~~. Although variability can be better understood, it cannot be reduced through further measurement or study, although it may be more precisely defined~~.~~. However, ~~at some point there are diminishing returns associated with the collection of additional data, and~~ the additional cost of further data collection may become disproportional to the reduction in uncertainty~~.~~. ~~Uncertainty can have two components: 1) variability in data or information, and 2) lack of knowledge. An uncertainty analysis conducted as part of a risk assessment focuses on issues of variability and knowledge uncertainty associated with each of the inputs and models used to derive the risk estimates.~~

~~Variability arises from true heterogeneity in exposure variables or responses, such as dose-response differences within a population or differences in contaminant levels in the environment. The values of some variables used in an assessment change with time and space, or across the population whose exposure is being estimated. Although variability can be better understood, it cannot be reduced through further study. Use of RME and CT scenarios provide an estimate of high-end and average exposures that may reasonably occur. The difference between the RME and CT risk estimates provides an initial evaluation of the degree of variability in exposure between individuals.~~

~~The second factor that generates uncertainty is a lack of knowledge about factors such as adverse effects or chemical concentrations. Uncertainty may be reduced by increasing knowledge about a factor through additional study, although it is impossible to gather enough data to eliminate uncertainty. In addition, at some point, there are diminishing returns associated with the collection of additional data; the cost of data collection is substantial and disproportional to the reduction in uncertainty. A~~

~~substantial amount of uncertainty is often inherent in environmental sampling as well as in the scientific models used in risk assessment.~~

The risks and hazards presented are consistent with EPA's stated risk management goal of being protective of 90 to 95 percent of the potentially exposed population~~.~~. However, these estimates are based on numerous and often conservative assumptions and, in the absence of definitive information, ~~.~~assumptions are used to ensure that actual sites risks are not underestimated~~.~~. The cumulative effect of these assumptions can result in an analysis having an overall conservativeness greater than the individual components~~.~~. Accordingly, it is important to note that the risks presented here are based on numerous conservative assumptions in order to be protective of human health and to ensure that the risks presented here are more likely to be overestimated rather than underestimated

~~6.0 This section includes a detailed analysis of uncertainties associated with each step of the BHHRA. However, a deterministic risk assessment alone cannot quantify the degree of conservatism in risk estimates, and this BHHRA does not include a probabilistic risk assessment, per agreement with EPA. This uncertainty analysis addresses variability and/or uncertainty in the inputs to the risk estimates, focusing on those inputs likely to have the greatest effects on the results of the risk analyses. A summary of uncertainties associated with this BHHRA and discussed in this section are provided in Table 6-1.~~

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6.1 DATA EVALUATION

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As discussed in Section 2, sediment, surface water, groundwater seep, and biota data were ~~data~~ collected during the RI.~~,~~ D~~as well as d~~ata of confirmed quality that meet the DQOs for risk assessment~~,~~ were used in this BHHRA to estimate ~~risks~~exposures~~.~~. Although uncertainty is inherent in environmental sampling, ~~Sediment, surface water, groundwater seep, and biota data were collected t~~The ~~for use in this BHHRA. U~~use of the EPA's DQO planning process (EPA 2000e) minimized the uncertainty associated with the data collected during the RI~~; however, some amount of uncertainty is inherent in environmental sampling.~~. ~~The following~~A discussion of key data evaluation uncertainties ~~have been identified~~is presented in the following sections.

6.1.1 Use of Target Species to Represent All Types of Biota Consumed

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Because it is not practical to collect samples of every resident fish and shellfish species consumed by humans within the Study Area, as recommended by EPA guidance (2000a), target resident species were selected to represent the diet of all ~~biota~~ types likely consumed by humans~~, as recommended by EPA guidance (2000a).~~. Four target species were collected to represent ~~resident fish tissue~~a diet consisting of resident fish: ~~(~~smallmouth bass, black crappie, common carp, and brown bullhead. ~~);~~ Crayfish and clam tissue samples~~and two species~~ were collected to represent a diet containing locally-harvested shellfish~~ diet (crayfish and clam).~~ . Factors considered in selecting the target species included~~:~~ likely consumption by humans, home range, the potential for bioaccumulation of COPCs, the trophic level of species, and their abundance.

~~The range of contaminant concentrations detected in the target species generally coincides with the range of concentrations detected in other species that were collected. Furthermore, the concentrations of~~ PCBs~~,~~ generally ~~which is the chemical group with~~ representing~~ing~~ the greatest ~~contribution~~ contributors to the estimated risks, ~~are~~ and detected concentrations are ~~generally~~ highest in smallmouth bass and common carp~~, both of which were included in this BHHRA.~~ . Therefore, the use of target resident species ~~to represent~~as representative of all biota consumed ~~should not~~is unlikely to ~~impact the conclusions of this BHHRA~~underestimate potential risks.~~, and may in fact overestimate risks, especially i~~If~~f~~ non-resident species are consumed, the risks may be less, commensurate with the amount of non-resident species present in the diet~~.~~.

6.1.2 Source of Chemicals for Anadromous and Wide-Ranging Fish Species

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~~NFor non-resident fish~~ S~~species, s~~almon, lamprey, and sturgeon have traditionally ~~were chosen as target non-resident fish species to~~ represented a substantial portion of the ~~tribal~~ fish ~~tissue~~ diet of tribal members~~.~~. T~~Due to the life cycles of these species, t~~hese ~~fish~~ species likely spend ~~some~~ a substantial portion of their lives outside of the Study Area~~. The time spent outside the Study Area may be significant for bioaccumulation of chemicals due to the growth, development, and feeding that occurs, as well as the relative amount of time spent within the Study Area versus outside of the Study Area~~, and thus contaminant concentrations in these species may bear little relationship to sediment concentrations in the Study Area~~.~~.

The Washington Department of Ecology analyzed returning fall Chinook salmon, as fillet tissue with skin, collected from three coastal rivers~~-~~ (the Queets, Quinault, and Chehalis Rivers) in 2004 (Ecology 2007). PCBs as Aroclors were detected at concentrations ranging from 5.0 µg/kg to 6.3 µg/kg in the Ecology study, relative to the maximum detected concentration of 20 µg/kg for salmon fillet tissue with skin collected from the Lower Willamette. The dioxin TEQ concentrations ranged from 0.09 picograms per gram (pg/g) to 0.23 pg/g in the Washington coastal rivers relative to the maximum detected concentration of 2 pg/g for salmon fillet tissue with skin collected from the Lower Willamette~~.~~. A comparison of the tissue concentrations from the Ecology study and the Lower Willamette indicates that the concentration of PCBs measured as Aroclors and congeners are noticeably greater in salmon collected from the Clackamas fish hatchery relative to concentrations detected in the Ecology study~~.~~. The reported concentrations of total DDT and dioxins as TEQs are generally consistent between the Ecology study and results from Portland Harbor~~.~~. These results are ~~presented~~ summarized in Table 6-2~~.~~. While the Chehalis River passes through some developed areas and therefore may have localized sources, both the Queets and Quinault Rivers are located almost entirely within Olympic National Forest and wilderness areas, so the potential for contribution from localized sources should be minimal~~. ~~. ~~These results indicate that sources of chemicals outside of the Study Area may contribute to bioaccumulation tissue concentrations of certain chemicals in anadromous fish species.~~

T~~here is a high degree of uncertainty as to the source of chemicals detected in non-resident fish species and whether~~ the degree to which ~~those chemicals~~contaminant concentrations in anadromous fish are ~~actually~~ due to exposures that occur within the Study Area is unknown~~. ~~. However, approximately 95 percent of the cumulative ~~risk from~~tribal fish consumption risk is due to ~~chemical concentrations~~ contaminants detected in resident ~~fish~~species, even though ~~resident fish~~ they only account for 50 percent of the estimated ~~mass of fish consumed~~diet~~. ~~. ~~Therefore, using the results of the BHHRA to focus onaddressing potential sources of chemicals contaminants potentially posing unacceptable risks in resident fish species should address sources of chemicals potentially posing unacceptable risks within the Study Area that contribute to concentrations in non-resident fish species as well.~~ As a result, the uncertainty associated with the source of chemicals to non-resident fish species should not ~~impact~~ affect the conclusions of this BHHRA~~. ~~.

6.1.3 Use of Either Whole Body or Fillet Samples to Represent ~~All~~ Fish Consumption

~~Chemicals bioaccumulate differently and are~~Different contaminants are preferentially accumulated in different parts of an organism~~. ~~. Organic compounds tend to accumulate ~~more~~ to a greater degree in ~~the fatty~~ tissues with a higher fat content, ~~and~~ while heavy metals accumulate more in muscle tissues~~. ~~. Thus, diets consisting of different parts of the fish would result in varying levels of exposure to the consumer~~.~~. The ~~chemicals~~ COPCs with the greatest contribution to the cumulative ~~cancer~~ risk and ~~with the highest noncancer HQ~~ hazard are persistent ~~PCBs~~chlorinated organic compounds (PCBs, DDx, and various PCDD/PCDF congeners)~~, which are organic compounds~~ that preferentially accumulate ~~preferentially~~ in fatty tissue~~. ~~. ~~Diets consisting of different fish parts result in varying levels of risk to the consumer. UsingAssuming a diet only of whole body or fillet tissue with skin to evaluate risk from all types of fish tissue diets is arepresents a conservative representation of actual consumption of fishassumption.~~ As discussed in Attachment F6, the difference in measured concentrations between fillet and whole body can be as great as a factor of 10 or more~~, dDepending on the species and chemical, the difference in measured concentrations between fillet and whole body tissue can be minimal negligible or more greater than a factor of 10, as discussed in Attachment F6.~~ ~~. ~~Since PCBs contribute to the vast majority of risks from tissue consumption on a Study Area-wide scale and on a localized scale for most exposure areas, this uncertainty could have a significant impact on the conclusions of this BHHRA. Alternatively, chemicals such as methyl mercury preferentially accumulate in muscle tissue, which means~~

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~~concentrations of mercury in fillet tissue would likely be higher than concentrations of mercury in whole body tissue.~~

Based on information presented in the Columbia Slough consumption survey (Adolfson 1996), the majority of fishers surveyed ~~are most likely to~~ consume only the fillet ~~portion of the fish~~, which may not include skin~~.~~. ~~Based~~ According to ~~on~~ the CRITFC ~~Fish Consumption~~ Survey (CRITFC 1994), tribal fish consumers are also most likely to consume ~~only~~ the fillet ~~portion of the fish, which may not include skin.~~. However, ~~because~~ some individuals or groups ~~may~~ consume other portions of the fish~~, and the assuming a whole body diet that includes is the most conservative estimate of potential cumulative risk from due to consumption of tissue fishconsumption, as organic chemicals have the greatest contribution to risk.~~. ~~. For an individual who consumes primarily fillet tissue, it would be appropriate to focus on risk results from fillet tissue consumption, recognizing that the risks are based on fillet with skin tissue and that risks associated with fillet without skin would likely be even lower for organic chemicals.~~

~~While it is not known to what extent consumption of non-fillet portions of fish occurs, this the BHHRA evaluated risks associated with consumption of only both fillet only and tissue or only whole body tissue.~~ Assuming a diet of whole body or fillet tissue with skin represents a conservative assumption and~~This approach~~ provides ~~the potential~~a range of risks associated with ~~the~~ different ~~diets~~dietary habits~~, and the risks from consumption of fillet tissue without skin would likely be even lower than those presented in this BHHRA. . IThr0 estimated risks for if an individuals who consumes mostly primarily fillets, but also occasionally other portions of the fish, the risks to that individual should would fall within the range of risks estimated estimates presented in this BHHRA. .~~. Because it is unlikely that a diet consists entirely of whole body tissue, the evaluation of risks associated with consumption of only whole body tissue provides a health protective approach.

6.1.4 Use of Undepurated Tissue to Represent Clam Consumption

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~~Clam O~~~~The majority of~~nly a limited number clam- tissue samples (five of 22) collected ~~throughout~~ in ~~most of~~ the Study Area ~~was~~ were not depurated ~~analyzed~~ prior to analysis~~;as undepurated samples, and only a limited number of clams samples were depurated before analysis.~~. Depuration ~~A~~ is a common practice in the preparation of clams ~~tissue~~ for human consumption ~~includes depuration~~, although ~~undepurated clam~~they may also be consumed undepurated~~.~~. ~~The amount of COPC-containingCOPCs may be adhered to sediment particles within the gut of bivalves can vary widely; however, studies have demonstrated that the sediment content in the gut of bivalves could represent up to 39% percent of the total body load of metals (Wallner-Kersanach et al. 1994).~~ With the exception of ~~a few~~ certain metals, average chemical concentrations detected in clam tissue in the Study Area were higher in undepurated ~~clam tissue collected at the Study Area~~ than in depurated ~~clam tissue collected at the Study Area~~samples~~.~~. However, depurated clam tissue ~~accounted for~~

~~only five of the 22 clam~~ samples were collected ~~for the BHHRA dataset, and these~~se ~~depurated samples were collected~~ from edges of the site ~~(~~at the northern and southern stretches~~). ~~, and the ~~Therefore, there are uncertainties associated with comparing depurated and undepurated tissue in the BHHRA dataset. These~~ concentrations are shown in ~~the EPC tables in Section 3 (~~Tables 3-24 and 3-25~~).~~ . Using the ~~analytical~~ concentrations ~~of~~ from undepurated ~~tissue to represent tissue consumption throughout most of the Study Area~~samples provides a health-protective approach to assessing risk from consumption of clams ~~tissue consumption~~.

6.1.5 Use of Different Tissue ~~Types~~ Sample Preparation to Assess the Same Chemical

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Samples ~~R~~of r~~For r~~esident fish tissue ~~samples~~ from ~~the~~ Round 1 were analyzed for ~~sampling event,~~ mercury ~~was analyzed~~ in fillet ~~tissu~~tissue ~~e~~ without skin~~. For resident tissue samples from the~~, while during Round 3, smallmouth bass and common carp ~~sampling event, mercuryit was~~samples were analyzed in fillet tissue with skin~~i. n The BHHRA resident species included in the Round 3 tissue sampling were smallmouth bass and common carp. ~~ . ~~These fillet~~The Round 1 and Round 3 datasets were combined for Study Area analysis~~.~~ . For the reasons presented in Section 6.1.3, the comparability of analytical data from fillet tissue with skin and fillet tissue without skin creates uncertainty in the BHHRA~~.~~ . Because mercury preferentially accumulates in muscle tissue, ~~one would expect mercury~~ concentrations would ~~to~~ be ~~slightly~~ expected to be higher in the fillet tissue samples without skin~~.~~ . However, for ~~the~~ smallmouth bass, mercury concentrations were generally higher in fillet tissue with skin, ~~and~~ while in common carp~~,~~ mercury concentrations were generally higher in fillet tissue without skin~~.~~ . A comparison of mercury tissue concentrations is provided in Table 6-3. The uncertainty associated with the use of different tissue types to assess risks from mercury should not ~~impact~~ affect the conclusions of this BHHRA~~.~~ .

6.1.6 Exclusion of Results Where Detection Limits ~~That Are Above~~Exceeded Analytical Concentration Goals ~~(ACGs)~~

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~~Uncertainty exists in the evaluation of chemicals that were not detected for which the method detection limits (DLs) exceed the ACGs.~~ Although s~~S~~ite-specific Analytical Concentration Goals (ACGs) were established for each media, ~~the . However,~~ ACGs for some chemicals ~~are exceptionally very low, and in some instances~~were ~~,~~not attainable some instances with present laboratory methods~~.~~ . DLs for chemicals that were analyzed but never detected were compared to the appropriate ACG for each media~~.~~, and the results of that analysis are presented in Tables 6-5 through 6-7~~.~~. ~~For~~ ~~In~~ ~~sediment, the~~ ~~maximum DLs exceed both ACGs and method reporting limits (MRLs) for *four* analytes (see Table 6-4).~~

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~~In tissue~~T, ~~he~~ ~~maximum DLs~~ ~~in tissue samples~~ ~~exceed ACGs and MRLs for eight analytes (see Table 6-5). Five chemicals were never detected in tissue, but their DLs~~

~~were below ACGs. It should be noted that DLs for PAHs were above the ACGs for PAHs, and PAHswhich were not detected in fish tissue samples collected in Round 1 fish tissue. However, because fish metabolize and excrete PAHs, 000and thus there is less likelihood for PAHsthey are less likely to bioaccumulate in fish. PAHs were detected in fish tissue samples collected in Round 3B fish tissue, as well as in Round 1, 2, and 3B shellfish tissue collected in Round 1, 2, and 3B. Thus, indicating thatthe data were sufficient to estimate risks from PAHs in both fish and shellfish tissue.~~

~~As discussed in Attachment F2, when a non-detected result was greater than the maximum detected concentration for a given exposure area, that result was removed from the dataset prior to calculation of an EPC. When a non-detected result was less than the maximum detected concentration, it was included in the dataset for calculation of EPCs according to the rules presented in Attachment F2. These data rules also apply to non-detected PAHs in Round 1 fish tissue. I~~

~~n addition, DLs for PCB congeners were elevated for some smallmouth bass tissue samples, which may add uncertainty to PCB TEQ estimates. However, the risks from total PCBs (due to detected congeners) were higher than the risks from the PCB TEQ for those exposure areas with elevated detection limits. Because the PCB congeners were detected in other smallmouth bass tissue samples, the elevated DLs were incorporated in the PCB TEQ estimates at one half the DL. Therefore, while the elevated detection limits contribute to uncertainty, using the elevated detection limits in this BHHRA should not significantly affect the risk results.~~

~~In the groundwater seep sample, The maximum DLs exceed were greater than both ACGs and MRLs for one two analytes in the groundwater seep sample (see Table 6-6). In surface water samples, the DL for five six analytes plus (including PCBs as Aroclors)PCB Aroclors exceed were greater than ACGs; the DL for two three analytes plus (including PCB Aroclors) was greater than the exceed MRLs (see Table 6-7). However, for surface water, PCB congener data were used instead of Aroclor data, as discussed in Attachment F2.~~

Chemicals that were not detected were not quantitatively evaluated ~~further~~ in ~~this~~ the BHHRA~~.~~. If chemicals were present at concentrations above the ACGs but below the DLs, those chemicals ~~could contribute to unacceptable risks~~would contribute to the estimated risk and hazard. However, given the number of chemicals that were detected at concentrations above their respective ACGs and the magnitude of difference between detected concentrations and ACGs, it is unlikely that exclusion of chemicals that were not detected would ~~impact~~ affect the conclusions of this BHHRA.

6.1.7 Removal of Non-Detected Results Greater Than the Maximum Detected Concentration for a Given Exposure Area

As discussed in ~~Attachment F2~~Section 3.4, if the DL for ~~a given~~ non-detected result was greater than the maximum detected concentration for an ~~exposure scenario and~~ exposure area, that result ~~was removed from the dataset prior00 to~~not included when calculating ~~on of~~the EPC~~s. ~~. These results are ~~discussed in Attachment F2 and~~ presented in tables F2-7 through F2-13~~. ~~. Inclusion of non-detected data greater than the maximum detected concentrations would likely have resulted in higher risk estimates in the risk characterization of the BHHRA.

6.1.8 Using N-Qualified Data

As discussed in Section 2.2.3 of the RI~~ report~~, ~~some~~ data were qualified using the “N” qualifier, ~~which indicates that~~when the identity of the analyte is not definitive~~. The use of the N qualifier is ~~, generally a result of the presence of an analytical interference in the sample~~. ~~. Examples include samples analyzed for ~~the~~chlorinated ~~of an analytical interference such as hydrocarbons or, in the case of pesticides, PCBs. P~~pesticide ~~data and SVOCs analyzed~~ by EPA Method 8081A, which were most commonly N-qualified as a result of analytical interference due to the ~~presecenee~~presence of PCBs in the samples~~. ~~. These N-qualified data were used in the BHHRA for calculating EPCs in fish and/or clam tissue~~. ~~. The following COPCs were included based solely using N-qualified data, and had ~~e~~Estimated cancer risks greater than 1 x 10^{-6} or HQs greater than 1 ~~following analytes~~ :~~were identified as tissue EPCs (for hexachlorobenzene and several other pesticides) that resulted in cancer risk estimates exceeding 1 x x 10^-6 or HIs exceeding 1.~~

- ~~Alpha~~alpha-~~hexachlorocyclohexane~~Hexachlorocyclohexane (fish tissue)~~,~~
- beta-hexachlorocyclohexane~~,~~ (fish tissue) ~~and~~
- gamma-hexachlorocyclohexane (fish tissue)
- Heptachlor epoxide (clam tissue)

~~were identified as contaminants potentially posing unacceptable risks greater than 1 x 10^-6 in fish tissue based on EPCs in fish tissue that were calculated using only N-qualified data only. Heptachlor epoxide was identified as a contaminant potentially posing unacceptable a risks risk greater than 1 x 10^-6 in clam tissue based only on N-qualified data only. ~~B~~While these contaminants were identified as contaminants potentially posing unacceptable risks based on the results of the BHHRA, it is important to note that there is uncertainty in b~~oth the identity and concentration of these contaminants in fish/clam tissue is uncertain~~. These contaminants~~, and they were not detected in abiotic media at levels posing risk to human health~~. ~~. ~~Attach~~A discussion of ~~ment F6 discusses~~ how EPCs and risk estimates would change for adult consumption of whole body fish tissue and shellfish tissue if N-qualified data were not included in the BHHRA dataset is presented in Attachment F6.~~.~~

6.1.9 Using One-Half The Detection Limit for Non-Detect Results in Summed Analytes

W~~As described in Attachment F1,~~ when ~~concentrations~~data are presented as summed values (e.g., total PCB congeners), one-half the detection limit ~~When~~ was used as a surrogate concentration when calculating the summed value for those ~~individual~~specific analytes reported as non-detect ~~when calculating the summed value.~~ . ~~an individual analyte that is part of a summed analyte (i.e. total PCB congeners, total endosulfans, etc.) was determined to be present in a given medium according to the rules for non-detects discussed in Section 2, but was not detected for a specific sample, one-half of the detection limit was used to calculate the summed analyte result, as described in Attachment F1. This value is assumed to represent a conservative estimate for the concentrations below the detection limit~~Use of one-half the detection limit assumes that there is equal probability that the actual concentration in the sample may be greater or less than the surrogate value~~, and introduces uncertainty into the summed analyte calculations.~~ . In general, the detection limits for non-detect results were low relative to detected concentrations~~.~~ . In addition, by only including those contaminants that were determined to be present in a given medium, the uncertainty associated with the use of non-detect results was minimized~~.~~ . ~~However, in cases where the detection limits were above analytical concentration goals and the chemical was detected infrequently, use of one-half the detection limit could impact the risk results.~~

6.1.10 Contaminants That Were Not Analyzed in Certain Samples

~~Per~~ Consistent with ~~the sampling and analysis plan that was~~as ~~approved by EPA,~~N ~~certain~~ not all fish tissue samples were analyzed for ~~a subset of the~~the same suite of analytes~~.~~ . For example, samples collected in Round 1 ~~fillet tissue samples~~ were ~~not~~ analyzed for PCB as Aroclors, but no analysis was done for ~~,~~dioxins ~~, or~~and furans ~~congeners~~~~were not measured.~~ . Fillet samples of s~~, while~~ ~~s~~ Smallmouth bass and common carp ~~fillet samples In~~ collected in ~~Round~~ Round 3B~~, smallmouth bass and common carp fillet tissue samples~~ were analyzed for ~~specific~~ PCB, dioxin, and furan congeners~~.~~ . In samples where congeners were analyzed, the risks from the total dioxin TEQ, which is not ~~included through other analytes~~otherwise measured ~~(i.e., risks from total PCBs are included through~~ as ~~PCBs as Aroclors)~~ comprise approximately 1 to 70 percent of the cumulative risks. ~~.~~ Therefore, the risks from consumption of black crappie and brown bullhead fillet tissue, which were only analyzed in Round 1, likely underestimate the actual risks particularly in those areas where PCBs and dioxin/furans are the predominant contaminants~~.~~ . ~~However, because~~ ~~a range of risks was calculated for fish consumption scenarios, which include~~ing~~d samples that were analyzed for congeners, so the lack of analysis of contaminants in certain samples should not impact~~ affect ~~the~~ overall ~~conclusions of this~~ the ~~BHHRA.~~

In addition, not all clam samples were analyzed for the same number of contaminants~~,~~ due to ~~lack of available~~limited tissue mass ~~for~~ of some composites collected during

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~~the~~ Round 2 ~~sampling efforts.~~ . Table 6-8 presents a listing of analyses not completed for ~~Missing analytes and associated sample identifications for clam tissue collected in Round 2 are shown in~~specific samples ~~Table 6-8.~~ . Additional samples were collected i~~I~~n Round 3B~~, additional clam samples were collected~~ and analyzed for ~~additional~~ a greater number of specific contaminants~~.~~. The Round 2 and Round 3B clam tissue data were combined and evaluated on a river-mile basis in the BHHRA~~.~~. Therefore, EPCs were available for almost all COPCs in each exposure area.~~. Lack of analytical values for COPCs in all samples within an exposure area may over or underestimate the risk for that exposure area. However, a range of risks was calculated for shellfish consumption scenarios, which included samples where all COPCs were analyzed, so the lack of analysis of contaminants in certain samples should not impact the conclusions of this BHHRA.~~

6.1.11 Chemicals That Were Not Included as Analytes

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~~It~~ As it is not ~~possible~~ practical to analyze for every chemical, ~~and thus~~specific chemicals and chemical groups were chosen for analysis based on an investigation of known or probable sources at in the LWR. ~~and pollutants~~~~contaminants.~~ . ~~Because~~ However, the chemicals expected to have the potential for significant contributions to risk are included in the risk assessment~~, chemicals not included as analytes introduce a low level of uncertainty to overall risk.~~ . The list of chemicals for analysis was determined in collaboration with EPA and its partners and ~~was included~~ presented in the approved sampling and analysis plan ~~that was approved by EPA.~~ . ~~Since then~~Subsequently, there has been interest in two additional groups of chemicals ~~that were not included as analytes in this BHHRA~~: polybrominated diphenyl ethers (PBDEs) and volatile organic compounds (VOCs) in tissue~~.~~. Risks have subsequently been assessed for exposures to PBDEs in in-water sediment and resident fish tissue, as presented in Attachment F3~~.~~.

VOCs were not analyzed in tissue or surface water~~the BHHRA tissue or surface water datasets~~ samples.~~.~~ Because of their nature, ~~of~~ VOCs~~, they~~ are not expected to accumulate in tissue to ~~a~~a sufficient degree ~~high enough~~ to pose significant risk via ~~tissue~~ consumption~~, especially given~~ relative to the other chemicals detected in tissue ~~that are clearly primary contributors to the calculated risk (e.g., PCBs).~~ . Given the magnitude of concentrations and toxicities of other chemicals that were ~~analyzed for and~~ detected in surface water and tissue, VOCs are unlikely to contribute significantly to the overall risks. Therefore, the lack of analysis for VOCs ~~should not~~is unlikely to ~~impact~~ alter the conclusions of ~~this~~ the BHHRA.

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~~As mentioned earlier in this section, it is impossible to analyze for every chemical, and there are a number of constituents analytes that have not been historically considered as contaminants but are recently gaining attention as research provides documentation that they are ubiquitous in the environment. These chemicals are generally referred to as "emerging contaminants,", and are not considered in this BHHRA, with the exception of PBDEs, which are discussed in Attachment F3. In~~

~~accordance with EPA guidance on risk assessment for superfund sites, this BHHRA assessed risks associated with CERCLA releases, and did not include studies focused on non-CERCLA releases, which include some recent studies on regional emerging contaminants. From a human health perspective, unregulated chemicals such as emerging contaminants may exist at the Site, but lack of knowledge and data regarding many of these chemicals precludes a human health risk assessment. Because emerging contaminants are not related to CERCLA releases for the Study Area, the lack of analysis for these chemicals should not impact the conclusions of this BHHRA.~~

6.1.12 Chemicals That Were Analyzed But Not Included in BHHRA

Not all detected chemicals ~~analyzed for~~ were included in the BHHRA~~. Specifically, not all conventional analytes or nutrient metals were analyzed for potential risk. Many conventional analytes are essential nutrients, and are not evaluated under the CERCLA program. The two conventionals that were included in this BHHRA are cyanide and perchlorate.~~ . The following a~~The conventional a~~nalytes ~~and metals that~~ were excluded from assessment are either because there are no suspected sources, or the analyte typically only present adverse health risks at high concentrations ~~listed here~~:

- Ammonia
- Calcium
- Calcium carbonate
- Carbon dioxide
- Chloride
- Ethane
- Ethylene
- Magnesium
- Methane
- Nitrate
- Nitrite
- Oxygen
- Phosphate
- Phosphorus
- Potassium
- Silica
- Sodium
- Sulfate
- Sulfide

~~7.0 Because of the lack of toxicity and/or essential nature of these analytes, exclusion of these chemicals from the BHHRA should not impact the conclusions of this BHHRA.~~

~~7.1.1~~6.1.13 Data Not Included in BHHRA due to Collection Date

Data collected after June 2008 were not included in ~~this~~ the BHHRA due to the completion schedule of ~~collection date of the data relative to~~ the RI/FS ~~completion schedule.~~ . These data sets are discussed in the Portland Harbor RI Report, and include a number of in-water sediment samples~~.~~ . ~~Because these data were not included in the BHHRA, there is uncertainty in the in-water sediment exposure scenarios.~~ However, due to the large spatial coverage of the existing in-water sediment BHHRA dataset, this uncertainty is not expected to ~~impact~~ affect the overall conclusions of ~~this~~ the BHHRA.

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~~7.1.2~~6.1.14 Compositing Methods for Biota and Beach Sediment Sampling

~~Compositing methods for biota and beach sediment sampling were designed to provide a conservative estimate of risk.~~ Compositing schemes ~~need to be~~were developed to be representative of the medium sampled ~~(grid pattern, stratified random, etc.)~~ and to be representative of ~~an~~ each exposure unit~~.~~.

Fish were composited based on an estimate of the average home range for each species (ODFW 2005)~~.~~. The home ranges for common carp and brown bullhead may be as large ~~as~~ or larger than the Study Area ~~and possibly even larger~~, ~~and~~ the home range for bass may be larger or smaller than the one mile assumed in the BHHRA~~.~~. For example, bass may only reside on one side of a river mile reach instead of throughout the one mile reach on both sides of the river ~~as assumed for the HHRA.~~. Smallmouth bass were composited on a river mile basis, while black crappie, brown bullhead, and carp were composited on a fishing zone basis. Fishing zones for brown bullhead and black crappie were from ~~RM~~ RM 3-6 and ~~RM~~ RM 6-9; fishing zones for common carp were from ~~RM~~ RM 0-4, ~~RM~~ RM 4-8 and ~~RM~~ RM 8-12 ~~as well.~~. ~~Uncertainty exists in this~~However, the compositing scheme ~~because the delineation of home range boundaries for the purposes of the risk evaluation are~~ represents only an approximation of the home ranges of the fish ~~samples actually~~ collected~~. However, composite samples~~, and typically consisted of five individual fish~~.~~. ~~, r~~Replicate composite samples were collected, and risks were evaluated using both ~~for individual sample locations~~the composite samples as well as on a Study Area-wide basis~~.~~. ~~Therefore, the compositing method for biota is not expected~~Where contaminants are evaluated on a harbor-wide basis and/or specific species are wide-ranging, this process is not likely to have an appreciable ~~to impact~~ effect on the conclusions of th~~is~~e BHHRA~~.~~. However, where samples are composited over an area larger than the actual home range of specific fish species, the result may either over- or underestimate risks, depending on the distribution of contaminant concentrations in the area over which samples are composited~~.~~. For example, the highest DDx concentrations are located on the west side of the river at RM- 7.5, while the EPC for smallmouth bass at that river mile combined data collected from both sides of the river.

Beach sediment was composited on a beach by beach basis, resulting in ~~one~~ a single sample result for each exposure area~~.~~. Uncertainty ~~exists in~~stems from this compositing scheme because the results of the risk evaluation are dependent on a single sample~~.~~. Composite samples are generally assumed to represent the area from which the individual samples of the composite were taken, but an unrepresentative individual sample (e.g., one representing extremely localized or ephemeral contamination) used in the composite could significantly bias the composite results~~.~~. The compositing scheme for beaches results in risk evaluation based on a single sample at a single point in time~~.~~. If a beach was found to pose an unacceptable risk, additional samples at that beach might be warranted~~.~~. However, all of the beach

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sediment exposure scenarios ranged from 8~~x~~ x 10^{-9} to 9~~x~~ x 10^{-5}, which are below or within the target risk range of 1 x 10^{-4} to1 x -10^{-6}.

~~7.1.3~~6.1.15 Mislabeling of Smallmouth Bass Fish Sample

One smallmouth bass sample collected from the west side of ~~RM~~ RM 11 (LW3-SB11W-11) during the Round 3 sampling event was incorrectly recorded as LW3-SB11E-01 (~~RM~~ RM 11 east) at the field lab~~.~~. This fish became part of the final LW3-SB11E-C00B and LW3-SB11E-C00F composite samples, which are the body and fillet composites from ~~RM~~ RM 11 east~~.~~. Fish SB11E-01 (actually from SB11W) accounted for 15~~%~~ percent of both sample types on a mass basis~~.~~. ~~This results in uncertainty in the concentration of the smallmouth bass sample from the east side of RM 11, since a fish from outside RM 11E was included in the composite.~~ However, since smallmouth bass exposure areas ~~are~~ were assessed on a river mile basis, the data from ~~RM~~ RM 11E and ~~RM~~ RM 11W were included in the same EPC calculations, and the effects of this uncertainty are not expected to ~~impact~~ affect the conclusions of this BHHRA~~.~~.

~~7.1.4 Use of DEQ Risk-Based Concentrations for Screening Values~~

~~4.0 EPA RSLs were used to screen chemicals detected in in-water sediment for the identification of COPCs. RSLs are not available for petroleum hydrocarbons, so DEQ risk-based concentrations (RBCs) for occupational surface soil exposure DEQ 2003) were used. DEQ does not have specific RBCs for lube oil, motor oil, or residual range hydrocarbons, so the screening value for generic oil was used as a surrogate. There is uncertainty associated with applying the screening value for generic oil to heavier oils, as lighter range petroleum hydrocarbons tend to be more toxic than heavier-range petroleum hydrocarbons. However, the maximum detected concentrations of these three oils in in-water sediment also does not exceed the screening value for the lighter range hydrocarbons detected within the Study Area (diesel, gasoline), so the uncertainty associated with the COPC screening values for heavier oils are not expected to impact the conclusions of this BHHRA.~~

~~7.1.5 Selection of Tissue COPCs Based On Detection of An Analyte~~

~~5.0 The selection of fish and shellfish tissue COPCs was based on whether an analyte was detected in each species/tissue type, and not based on a comparison with health-protective screening levels. There is uncertainty associated with identification of tissue COPCs based on detections alone, and this could potentially impact the conclusions of this BHHRA.~~

~~7.2~~6.2 EXPOSURE ASSESSMENT

Uncertainties that arise during the exposure assessment can typically have some of the greatest ~~impacts~~ effect on ~~the~~ risk estimates~~.~~. The following subsections address

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uncertainties associated with exposure models, exposure scenarios, exposure factors, and EPCs used in the risk estimates.

~~7.2.1 Model Applicability~~

~~6.0 The standard exposure models used to estimate risks may result in uncertainty. The exposure models rely on identification of exposure scenarios and selection of appropriate exposure factors for those scenarios. Uncertainty in the applicability of the exposure scenarios will result in uncertainty in the risk estimates. Site-specific exposure scenarios were developed to provide a conservative estimate of risk within the Study Area, using conservative exposure factors to represent both reasonable maximum and central tendency exposures that could hypothetically occur within the Study Area. While uncertainties associated with the exposure models could impact the conclusions of this BHHRA, the models used are consistent with applicable risk assessment guidance and are a source of uncertainty in all risk assessments.~~

~~7.2.2~~6.2.1 Subsurface Sediment Exposure

A complete exposure pathway ~~needs to include~~requires the presence of a retention or ~~a~~ transport medium, an exposure point, and an exposure route~~ –~~. Subsurface sediment was not considered an exposure medium ~~for this~~in the BHHRA because it was assumed that ~~any~~ potential human contact with river sediment below 30 cm in depth was unlikely, ~~and~~ or that if it does occur, the frequency and extent would be minimal~~.~~. Situations ~~in~~ which may result in human exposure to subsurface ~~might occur~~ include: potential scouring, natural hydraulic events that are not well understood, future development of near-shore and upland properties, maintenance of the ~~federal~~ navigation channel, ports, and docks, placement and maintenance of cable and pipe crossings, pilings and dolphins, anchoring and spudding of vessels, and exposure to propeller wash from vessels~~ –~~. ~~All of these situations could provide minimal impact to subsurface in-water sediment as well as to surface sediment, and thus the assessment of risk from exposure to surface sediment would be adequately protective of potential exposure to subsurface sediment. However, the uncertainty associated with not directly assessing subsurface sediment exposure could underestimate risks from multiple exposure pathways for the Study Area.~~ Due to the low ~~levels~~ potential of ~~possible~~ exposure to subsurface sediment, ~~this uncertainty is not expected to impact the conclusions of this~~the estimates presented in the BHHRA are considered sufficiently representative of baseline exposures.

~~7.2.3~~6.2.2 Potential Exposure Scenarios

Some of the ~~exposure scenarios evaluated in this BHHRA have limited documentation regarding the actual extent of exposure to receptors in the Portland Harbor. These scenarios were included in this BHHRA at the direction of EPA Region 10. The~~ uncertainties associated with the~~se~~ exposure scenarios~~-~~ evaluated in the BHHRA are ~~are~~ discussed in the following subsections~~ –~~.

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~~7.2.3.1 Human Milk Consumption~~

~~7.0 The BHHRA evaluated risks to an infant consuming human breastmilk for receptors exposed to bioaccumulative compounds selected as COPCs. The evaluation of this pathway was performed consistent with DEQ guidance (2010), but there are a number of uncertainties associated with modeling infant exposure to contaminants through breastmilk based on exposure to the mother, which could potentially affect the outcomes of this BHHRA.~~

~~8.0 Risks to an infant consuming breastmilk from the adult receptors evaluated in this BHHRA resulted in risks above the EPA points of departure for cancer and noncancer endpoints. However, breastfeeding is still the healthiest way to feed a baby, even if the milk contains contaminants. Even though infants may receive a dose of contaminants from their mothers' milk, human milk also contains hundreds of healthy nutrients, vitamins, minerals, and immune system boosters. These natural, healthy substances more than compensate for any health risks from contaminants and may even help repair damage caused by contaminants before the baby was born. Breastfeeding has been shown to boost immunity and IQ and prevent many diseases. Calculated risk to infants from breastfeeding presented in this report should not discourage any mother from breastfeeding her infant (adapted from DEQ, 2010).~~

~~7.2.3.2~~6.2.2.1 Shellfish Consumption

~~This BHHRA evaluated risks from shellfish consumption based on crayfish and clam tissue data. However, the harvest or possession of Asian clams, which is the species assessed in this BHHRA, is illegal.~~

A commercial crayfish fishery ~~exists has existed~~exists in the LWR, and c~~. C~~rayfish landings must be reported to ODFW by water body and county~~.~~. Per ODFW, the crayfish fishery in the LWR is not considered a large fishery (Grooms 2008), and ~~. Based on ODFW's data for 2005 to 2007,~~ no commercial crayfish landings were reported for the Willamette River in Multnomah County from 2005 to 2007~~.~~. DHS had previously received information from ODFW indicating that an average of 4,300 pounds of crayfish were harvested commercially from the portion of the Willamette River within Multnomah County each of the five years from 1997-2001. In addition to this historical commercial crayfish harvesting, DHS occasionally receives calls from citizens who are interested in harvesting crayfish from local waters who are interested in fish advisory information. According to a member of the Oregon Bass and Panfish club, crayfish traps are placed in the Portland Harbor Superfund Site boundaries and collected for bait and possibly consumption (ATSDR 2006)~~.~~. It is not known to what extent non-commercial harvesting of crayfish occurs within the Study Area, if at all, or whether those crayfish are consumed and/or used for bait.

Evidence of current consumption of freshwater clams from Portland Harbor is ~~largely anecdotal~~limited~~.~~. ~~The only reported clam consumption was from~~According to a project conducted by the Linnton Community Center (Wagner 2004), transients reportedly consume clams from the river on a limited and infrequent basis~~.~~. As part of the project, conversations were conducted with transients about their consumption of fish or shellfish from the Willamette River~~.~~. These conversations were not conducted by a trained individual ~~nor~~ and were ~~the conversations~~not documented~~.~~. T~~he t~~ransients ~~that were contacted~~ reported consuming various fish species, as well as crayfish and clams, and ~~. M~~many ~~of the individuals~~ indicated that they were in the area temporarily, move from location to location frequently, or have variable diets based on what is easily available~~.~~. Assuming that clam consumption occurs, the Linnton Community Center project suggests that it does not occur on an ongoing basis within the Study Area~~.~~. DEQ and EPA staff have occasionally received calls from individuals who claim to have harvested clams and are inquiring whether consumption is safe, and individuals of apparent southeast Asian descent have been observed harvesting clams from the shore in Portland~~.~~. However, the actual extent to which freshwater clams or other shellfish are currently harvested and consumed is not known.

~~The evaluation of risks from shellfish consumption in this BHHRA is a health protective approach.~~

~~7.2.3.3~~6.2.2.2 Wet Suit Divers

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Commercial diving companies in the Portland area were contacted to develop a better understanding of potential diver exposures within the Study Area~~.~~. All of the diving companies that were contacted indicated that the standard of practice for commercial divers is the use of dry suits and helmets when diving in the LWR (Hutton 2008, Johns 2008, and Burch 2008)~~.~~. EPA Region 10 reported observing divers in wet suits and with regulators that are held with the diver's teeth within the Study Area~~, so a wet suit diver and associated ingestion for the "in the mouth" regulator exposure scenarios were included at the direction of EPA.~~. ~~Evaluation~~ An evaluation was also performed of helmet diving with use of a neck dam, which allows can allow ~~polluted~~ water ~~leakage~~ to leak into the diving helmet~~.~~. Commercial divers as recently as 2009 have been observed using techniques to don a diving helmet which increase exposure (Sheldrake personal communication with RSS, 2009, DEQ, 2008). The observed wet suit divers were performing environmental investigation and remedial activities, which are not activities evaluated as part of a commercial diver scenario~~.~~. Also, it is not known whether the individuals who were observed diving in wet suits on specific occasions are diving within the Study Area on a regular basis, as they do not work for the commercial diving companies in the Portland area~~.~~. Recreational diving also takes place in Portland Harbor (Oregon Public Broadcasting Think Out Loud, "Are you going to swim in that?" August 22, 2008). Therefore, including a wet suit diver scenario with associated ingestion from use of a recreational type regulator, rather than a full face mask or diving helmet, and full body dermal exposure in this BHHRA (in addition to a dry suit diver scenario) is a conservative approach.

~~7.2.3.4~~6.2.2.3 Domestic Water Use~~rs~~

The ~~domestic water user risks~~evaluation of surface water as a domestic water source ~~are~~ is based on the ~~hypothetical use of~~assumption that ~~untreated~~ surface water is drawn from the Study Area ~~as a domestic water source.~~ . Within t~~Surface water in t~~he Study Area, the LWR ~~within the Study Area~~ is not currently used as a domestic water source~~.~~ . According to the City of Portland, the primary domestic water source for Portland is the Bull Run watershed, which is supplemented by a groundwater supply from the Columbia South Shore Well Field (City of Portland 2008)~~.~~ . In addition, the Willamette River was determined not to be a viable water source for future water demands through 2030 (City of Portland 2008)~~.~~ .

~~Under OAR 340-041-0340 Table 340A, domestic water supply is a designated beneficial use of the Willamette River, but only with adequate pretreatment and natural quality that meets drinking water standards. The use of the Willamette River as a domestic water source would only occur after adequate pretreatment to meet Safe Drinking Water Act standards and Oregon rules. As a result, the term hypothetical was used to describe the scenario, which was based on the use of untreated surface water.~~

Therefore, the evaluation of ~~untreated~~ surface water as a domestic water source~~, even under hypothetical future conditions,~~ is a conservative approach and is not based on current knowledge of future planned uses of the Willamette River within the Study Area as a domestic water ~~source or based on Oregon rules that require adequate pretreatment~~.

~~7.2.4~~6.2.3 Potentially Complete and Insignificant Exposure Pathways

Exposure pathways that have been determined to be potentially complete and insignificant were not evaluated further in this BHHRA~~.~~ . As described in Section 3.2, these exposure pathways have a "source or release from a source, an exposure point where contact can occur, and an exposure route by which contact can occur; however, the pathway is considered a negligible contributor to the overall risk."~~.~~ The exposure pathways identified as potentially complete and insignificant were related to Willamette River surface water exposures to populations evaluated in this BHHRA~~.~~ . ~~The~~ Ingestion and dermal absorption of chemicals from surface water were quantitatively evaluated for the populations that are expected to have the most frequent contact with surface water ~~(transients, recreational beach users, and hypothetical future residents) as well as the EPA directed evaluation of surface water exposure to divers were quantitatively evaluated in this BHHRA for ingestion and dermal absorption of chemicals from surface water.~~ . ~~The populations for which s~~Surface water exposures were not evaluated were for dockside workers, in-water workers, tribal fishers, and fishers~~.~~ . ~~For several other populations, only the inhalation exposure pathway was determined to be insignificant. These populations were transients, divers, recreational beach users, and hypothetical future residents.~~

Th~~is~~e BHHRA identified and evaluated the exposure pathways that were expected to result in the most significant exposure to COPCs in the Study Area~~.~~ . The magnitude

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of exposures experienced by populations for these exposure pathways are typically expected to be much greater than that expected for the exposure pathways identified as “insignificant.”~~.~~

Thus, the assessment of risk to populations from exposure pathways that were quantitatively evaluated in this BHHRA would be adequately protective of exposed populations in the Study Area~~. ~~. However, the uncertainty associated with not directly evaluating~~ “insignificant”~~ exposure pathways considered insignificant could underestimate risks for the Study Area~~. ~~. Due to the low ~~levels of possible~~potential of exposure for these ~~“insignificant” exposure~~ pathways, this uncertainty is not expected to impact the conclusions of this BHHRA.

~~7.2.5~~6.2.4 Exposure Factors

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Assumptions about exposure factors typically result in uncertainty in any risk assessment~~. ~~. As discussed previously, the scenarios evaluated are representative of exposures that could occur in the Study Area under either current or future conditions~~.~~. RME and CT values were used for ~~some of~~ the exposure scenarios to ~~evaluate~~ help assess the overall ~~impact~~ effect that variability in each of the exposure assumptions has on the risk estimates~~. ~~. ~~As discussed previously, most of the RME scenarios represent the reasonable maximum exposures that could occur in the Study Area under current and future conditions. In the case of the scenarios assessing the use of untreated surface water as a domestic water source, both the RME and CT scenarios represent hypothetical exposures. The other CT exposure scenarios represent the expected average or mean exposure for exposures that could occur in the Study Area in the present and future.~~ The range of risk estimates between these two exposure scenarios provides a measure of the uncertainty surrounding these estimates~~. ~~.

~~For fish consumption~~A~~, a~~ range of ingestion rates for fish consumption were used to evaluate variability on the risk estimates~~ (see discussion of exposure parameters for tissue ingestion scenarios below). As recommended by EPA guidance, these ingestion rates were used with EPCs calculating using both the mean and 95% percent UCL on the mean (or maximum concentrations for EPCs when sample size was less than 5)~~, ~~and~~ thus the resulting risks in this BHHRA represent a range of possible ~~human health risks~~outcomes, including estimates that ~~might~~ may be representative of the upper range of plausible exposures~~fall into the high end of those possible. ~~.

~~In addition to the variability, there is also uncertainty associated with the exposure factors that were used in this BHHRA.~~

The following exposure factor uncertainties have been identified and analyzed further to determine the potential effects on the risk estimates:

~~7.2.5.1~~6.2.4.1 Exposure Parameters for Sediment Exposure Scenarios

The parameters used in the BHHRA to evaluate beach and in-water sediment exposure ~~parameters~~ used ~~in this BHHRA~~ were intended to provide conservative estimates ~~of~~ based on potential uses ~~for~~ in the Study Area.

Beach areas that are accessible to the general public were identified as potential human use areas, even though it is not known whether recreational beach use actually occurs at these locations~~. Even if beach use occurs,~~, and the extent to which the beach ~~is~~ may be used and the nature of the contact with sediments~~/beach~~ is unknown~~.~~. Future changes in land use may make some beach areas ~~more~~ more- or ~~less~~ less-accessible to the general public~~for humans~~, which increases uncertainty about future exposure~~.~~. ~~For~~ When evaluating in-water sediment, ~~every~~ each ~~½~~ on-half mile river mile segment on each side of the navigation channel was considered a potential exposure area for all in-water sediment exposure scenarios, regardless of the feasibility or practicality of use of the area~~.~~. Information from this approach can be used to info~~rm RM~~rm the public about relative risks throughout the river and can help focus the feasibility study~~, but likely over-estimates risk estimates for in-water sediment~~.

There are uncertainties ~~The~~ associated in the selection of the exposure duration, frequency, and intake parameters ~~for~~ used to evaluate both beach and in-water sediment ~~also have associated~~exposures ~~uncertainties.~~. These scenarios assume ~~exposure to the~~long-te~~rm RM~~rm repeated use of the same beach or ~~½~~ one-half mile river mile segment, which may not accurately reflect actual use practices ~~for an entire childhood, or 25 to 70 year exposure duration for adults, depending on the receptor.~~. The exposure ~~Frequency~~ frequencies evaluated ~~of exposure~~ range~~s~~ from ~~94~~ 94 days/year up to 250 days/year~~.~~. Default intake parameters for soil exposure were generally used; however, to account for an assumed greater moisture content of beach sediments, the dermal adherence factor ~~(dermal contact with sediment) for a~~used to evaluate child recreational beach ~~user~~ exposure was ~~more than 10 times~~10-fold greater than the default for soil~~.~~.

~~Another uncertainty associated with exposure parameters for sediment is the dermal absorption factor, which does not exist for all COPCs. Per~~Consistent with EPA guidance (2004), only those compounds or classes of compounds for which dermal absorption factors ~~exist~~ are available were quantitatively evaluated ~~quantitatively for~~via ~~the~~ dermal contact exposure~~ pathway.~~. ~~For compounds~~COPCs for which ~~without~~ dermal absorption factors were not available were not quantitatively evaluated, as dermal absorption was essentially assumed to be zero~~.~~. However, as the majority of COPCs were quantitatively evaluated~~, which for the sediment COPCs are certain metals and perchlorate, dermal intake was assumed to be zero. However, dermal absorption factors exist for the chemicals and chemical groups that are likely to pose the greatest concern for risk from dermal contact. So although the lack of dermal absorption factors for all COPCs may underestimate risk from dermal contact~~

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~~with sediment for certain metals and perchlorate,~~ this uncertainty ~~would~~ does not substantially change the conclusions of this BHHRA~~.~~.

Most of the uncertainties associated with the sediment exposure parameters are likely to overestimate the risks associated with direct exposure to sediment~~.~~. ~~However, all of the beach sediment exposure scenarios were below or within the target risk range of 1 x x 10^{-4} to 1 x x 10^{-6}, and with the exception of two segments specifically for the tribal fisher RME scenario, all of the in-water sediment exposure scenarios were also below or within the target risk range of 1 x x 10^{-4} to 1 x x 10^{-6}. For the tribal fisher RME scenario, the exposure parameters are especially conservative as it is unlikely that an individual would fish the same ½-river mile river segment for five days every week of every year for 70 years.~~

~~7.2.5.2~~6.2.4.2 Exposure Parameters for Surface Water and Groundwater Seep Exposure Scenarios

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~~Transients were assumed to be exposed to surface water through ingestion and dermal contact. Tap water ingestion rates were used to represent exposure to surface water via ingestion for transients. However, tap water ingestion rates are an estimate of ingestion of a drinking water source, and the use of untreated water from the Lower Willamette as a source of drinking water by transients on an ongoing basis for two years is assumed to be health protective. The tap water ingestion rate used in the risk evaluation was 2 L/day for the transient and assumes surface water will be ingested every day for two years. In addition, it was assumed that transients bathe directly in the Lower Willamette two days per week throughout the entire year for two years.~~

~~For the recreational beach users, exposure to surface water was assumed to occur through incidental ingestion and dermal contact while swimming in the Lower Willamette. The incidental ingestion rate of 50 milliliters per day (ml/day) used in this BHHRA is that recommended by EPA for a swimming scenario. The exposure scenario assumes that adults frequent the same quiescent water area 26 times per year for 30 years, and that children frequent the same area 94 times per year for six years.~~

~~In addition to the direct contact scenarios mentioned above, risks were assessed from exposure to surface water as a hypothetical future domestic water source. This scenario assumes untreated surface water is used as a domestic water source 350 days a year for 30 years (adult resident) or six years (child resident). The LWR within the Study Area is not currently used as a domestic water source, but could be used as such in the future.~~

~~Another exposure parameter resulting in uncertainty for the surface water and groundwater exposure parameters is the absorbed dose per event. This parameter was derived per EPA guidance (2004) using chemical-specific factors, but the factors for some of the COPCs fall outside of the predictive domain. Specifically,~~Although dermal absorption of PAHs from water was quantitatively evaluated in the BHHRA, the dermal permeability coefficient (K_p) falls outside of the effective predictive domain (EPD) for a number of the PAHs, including the following ~~COPCs~~:

- Benzo(a)anthracene
- Benzo(a)pyrene
- Benzo(b)fluoranthene
- Indeno(1,2,3-cd)pyrene
- Dibenzo(a,h)anthracene

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EPA dermal assessment guidance (EPA 2004) states that "~~Although~~ although the methodology [for predicting the absorbed dose per event] can be used to predict dermal exposures and risk to contaminants in water outside the EPD, there appears to be greater uncertainty for these contaminants."~~–~~ The range of uncertainty associated with the Kp value can be several orders of magnitude~~—~~. For instance, the predicted Kp value recommended by EPA (2004) for benzo(a)pyrene is 0.7 centimeters per hour (cm/hr), while the range of predicted Kp values presented by EPA (2004) is 0.024 cm/hr (95~~%~~ percent lower confidence level) to 20 cm/hr (95~~%~~ percent upper confidence level)~~—~~. This uncertainty could result in over-estimation or under-estimation of risk from exposure to surface water~~—~~. With the exception of arsenic, the only exceedances of 1 ~~x~~ x 10^{-6} risk from surface water scenarios are the result of dermal exposure to PAHs in surface water~~—~~. However, all of the surface water exposure scenarios were below or within the target risk range of 1 ~~x~~ x 10^{-4} to 1 ~~x~~ x 10^{-6}.

~~7.2.5.3~~6.2.4.3 Exposure Parameters for ~~Tissue Ingestion~~Fish/Shellfish Consumption Scenarios

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Site-specific information regarding fish consumption is not available for Portland Harbor~~—~~. In the absence of specific data, fish consumption data representative from several sources was considered and selected as being representative of the general population of the greater Portland area, as well as that portion of the population that actively fishes the Lower Willamette and utilizes fish from the river as a partial source of food~~—~~. ~~The exposure parameters used for to evaluate tissue ingestionfish consumption were designed to provide a conservative estimates of exposurerisk. Fish tissue ingestion rates were developed using fish consumption data from a national study of fish consumption (CSFII, USDA), from a creel survey of Columbia Slough fishers north of the Study Area, and from the CRITFC Columbia River Fish Consumption Survey (CRITFC) study. The CRITFC Fish Consumption Survey provides fish consumption data for the Columbia River Basin for four of the six tribes who are parties to the Consent Decree for the Portland Harbor site. In addition, although the Columbia Slough Study was not done in Portland Harbor , the Columbia Slough is within one-half mile of the northern part of the Portland Harbor site, so fishers in the Portland Harbor site may have similar fishing practices and fish consumption rates as those fishing in the Slough.~~

~~Site-specific~~ information regarding ~~fish consumption information is not available for the fisher scenarios~~Portland Harbor. ~~As a result~~In the absence of specific data, ~~nationwide fish consumption data~~ ~~representative from several sources was~~ ~~were used to calculate target fish tissue levels~~~~considered and selected as being representative of the general population of the greater Portland area, as well as that portion of the population that actively fishes the Lower Willamette and utilizes fish from the river as a partial source of food~~. ~~A consumption study conducted for the Columbia Slough was also used. The 99th percentile rate from the nationwide Continuing Survey of Food by Individuals,~~ However, the rates presented in the CSFII ~~(United States Department of Agriculture [USDA] 1998) of 142 g/day (as calculated in USEPA Estimated Per Capita Fish Consumption in the United States, freshwater and estuarine fish and shellfish) was used as one ingestion rate for adult fishers in the BHHRA. The 90th percentile rate of 17.5 g/day from the same study was used also used as one of the ingestion rates for adult fishers in the BHHRA. Concerns have been expressed regarding the methodology used by EPA in this study to establish the fish consumption rates, which are also recommended as default AWQC subsistence fish consumption rates in EPA's WQC Human Health Methodology guidance (EPA 2000d). Criticisms of these rates have been raised because they are based on~~study represent per capita consumption rates ~~from the general population—that is, "fish consumption" rates that are estimated based on the combined consumption information from fish consumers and fish non-consumers alike. For~~rather than true long-te~~rm RM~~ rm averaged consumption rates~~.—~~. Further, the large range between the percentile values ~~are~~is indicative of substantial variability in the underlying data~~.—~~. For example, consumption rates consumers ~~the~~ are 200 g/day at the 90th percentile ~~rate for fish consumers is 200 g/day, while~~ and 506 g/day at the ~~90th~~ 99th percentile~~.—~~. ~~rate including data regarding fish~~ The consumption rate for consumers and non-consumers is ~~about~~ approximately 18 g/day at the 90th percentile and 142 g/day~~.~~ ~~Similarly,~~ at the 99th percentile ~~value for fish consumers is about 506 g/day, while the 99th percentile is approximately 142 g/day.~~ . ~~when data including the lack of fish in the diet of non-consumers are added. As previously discussed~~~~There is a large difference in the percentiles of the dataset when information from people who do not consume fish are included. The consumer-only ingestion rates likely overestimate actual ingestion rates because people who do consume fish but did not on the 2 days of the study (e.g., many infrequent consumers) are not included in consumers only rate. At the same time, EPA guidance (1989) recommends using the 95th percentile, or even the 90th percentile, for RME~~~~upper-bound values for contact values~~~~rates when evaluating RME. However, the data are indicative that considerable variability exists in fish consumption rates. In addition~~As discussed in Section 3.5.9.6, the RME consumption rate selected for recreational fishers ~~The the 95th UCL rate~~of 73 g/day is based on data from the Columbia Slough study ~~was used in the BHHRA as the the RME consumption 73 g/day rate for adult recreational fishersconsumers in the BHHRA.~~ . ~~The Columbia Slough Study~~That study was a creel survey~~.~~, and the representativeness of the~~is~~ rate is dependent on several factors. ~~As a result, the consumption rates used in the BHHRA may overestimate or underestimate actual fish~~

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~~consumption rates in the Study Area. This is due to many reasons,~~ including but not limited to:

- Willingness of anglers to participate
- Communication. If a substantial number of anglers consist of 1^{st} or 2^{nd} generation ethnic minorities, then language may be a barrier.
- Discrepancy between individuals who catch fish and those who prepare meals~~.~~ . Men generally fish but women generally prepare seafood and are much more familiar with the mass of seafood consumed.
- Difficulty in translating from the items inspected in an angler's basket to portion sizes and amounts consumed, since this requires assumptions about edible portions and cleaning factors.
- Lack of a random or representative sample~~. ~~. Interviewers can only speak with who they encounter.
- Timing and seasonality of interviews.
- Weather conditions may bias the results of any day's interviews.

In addition ~~to the uncertainties behind~~ to the ~~rates of fish~~ consumption~~,~~ rates, ~~it was assumed that the frequency of consumption occurred at the same ingestion rate for 30 years for the adult fisher scenarios. Furthermore~~uncertainty also exists with respect to the relative percentage of the diet of obtained from the Study Area versus other nearby sources of fish, and the degree to which different methods of preparation and cooking may reduce concentrations of persistent lipophilic contaminants~~, 100% percent of the fish consumed was assumed to be caught within a 1 mile stretch on both sides of the river for bass and within a 3 mile stretch on both sides of the river for crappie, carp and bullhead trout over 30 years for localized exposures.. No reduction in concentrations of contaminants during food preparation and cooking was assumed, although reductions can occur depending on cooking and methods of preparation.~~ .

~~For the tribal fish consumption scenario, the 95th percentile rate from the CRITFC Fish Consumption Survey (CRITFC 1994) was used. The CRITFC Fish Consumption Survey was performed by interviewing four of the six tribes who are natural resource trustees for the Site. It is not clear how this would impact the fish consumption rate for tribal populations used in the BHHRA, which was based up on the CRITFC Fish Consumption Survey.~~Uncertainties associated with tribal consumption rates largely relate to limitations inherent in the CRTFIC consumption survey on which the consumption rates used in the BHHRA are based~~.~~. ~~Also, some published articles have suggested that the fish consumption rates in the CRITFC Fish Consumption Survey~~These consumption rates may ~~a~~b~~r~~e biased low for tribal members because:

- Tribal members who have a traditional lifestyle (and likely a higher consumption rate) would have been unlikely to travel to the tribal offices that were used for administering the CRITFC fish consumption interviews.

- The fish consumption rates for some tribal members that were perceived as being outliers (consumption rates were too high) were dropped from the CRITFC data before the consumption rates were calculated.
- Current fish consumption rates may be suppressed and, therefore, do not reflect the potential of the higher consumption rates if fishery resources improved or if~~–~~ contaminant concentrations in the water body decrease.

~~While the tribal fish consumption rates may or may not be biased low, there were additional conservative assumptions incorporated in the tribal fish consumption scenario. For example, fish consumption by an adult tribal fisher was assumed to occur at the same rate every day of every year for 70 years. As with the fisher scenarios, it was assumed that 100% percent of the fish consumed was caught at the same location for 70 years, and no reduction in concentration of contaminants occurred during food preparation or cooking.~~Conversely, conservative assumptions were used with respect to exposure frequency and duration, as well as the relative contribution of fish from the Lower Willamette to the overall tribal diet. ~~The~~ According to the CRITFC s~~C Fish Consumption S~~urvey, ~~that was used as the basis for the tribal fish ingestion rate also indicated that~~ none of the respondents fished the Willamette River for resident fish and at most, approximately 4~~%~~ percent fished the Willamette ~~River~~ for anadromous fish~~.~~. However, future use of the site by tribal members may change i~~. Tribal members who have a traditional lifestyle and were unlikely to travel to tribal offices for the CRITFC Fish Consumption Survey also may be unlikely to travel to Portland Harbor to fish. It is unknown to what extent future tribal fishing habits may change i~~f fishery resources improved~~ or if COC concentrations in the water body decrease. . ODEQ is proceeding with development of state water quality limits based on a tribal ingestion rate of 175 g/day.~~

I~~The i~~nformation ~~suggesting~~ regarding consumption of ~~that~~ shellfish ~~consumption may occur at~~from the Study Area ~~comes from a~~relies in part from information obtained from a community project sponsored by the Linnton Community Center, as discussed in Section 3.3.6~~.~~. However, it is not known to what extent shellfish consumption actually occurs~~.~~. Because site-specific shellfish ~~ingestion~~ consumption rates are not available, nationwide CSFII (USDA 1998) shellfish consumption data were used~~ to calculate target tissue levels for clams and crayfish. . The 95th percentile rate for shellfish consumption for freshwater and estuarine habitats combined from the nationwide survey was the source of the18 g/day ingestion rate, and the mean rate from the nationwide survey was the source of the 3.3 g/day ingestion rate.~~ As with the rates for fish ~~ingestion~~ consumption~~rates for adult consumers~~, these ~~shellfish ingestion rates~~ are based on per capita consumption rates from the general population. ~~– that is, consumption rates that include shellfish consumers and non-consumers alike. Consumer-only rates were not calculated in the EPA document for shellfish alone, but it is likely that they are higher for consumers-only compared to the rate based on both consumers and non-consumers.~~ In the nationwide survey, shrimp ~~, which is not found within the Study Area,~~ accounted for more than 80~~%~~ percent of the shellfish consumed~~.~~, ~~Crayfish~~ crayfish accounted for less than ~~1%~~one percent of ~~the shellfish consumed~~diet, and freshwater clams were not included in the nationwide survey~~. ~~. It is not known to what extent fishers substitute alternative local types of shellfish~~. ~~. However, ~~for freshwater habitat only, which is the same as the Study Area,~~ the mean nationwide shellfish consumption rate from freshwater sources is 0.01 g/day; upper percentiles for freshwater shellfish consumption rates are not available (EPA 2002b).

~~Daily shellfish consumption rates used in this BHHRA represent mathematical artifacts to account for annual consumption rates. The daily consumption rates for shellfish represent approximately two and a half 8-ounce meals per month (18 g/day ingestion rate), and just less than one 8-ounce meal every two months (3.3 g/day ingestion rate). As with fish, 100 percent of the shellfish was assumed to be caught from the same one-mile stretch of river, on the same side of the river, for the 30 years, and no losses in chemical concentration were assumed from food preparation or cooking. It is unlikely that the Study Area supports *Corbicula* populations large enough to supply the quantity of tissue needed to satisfy the ingestion rates used in the BHHRA. During the Round 2 sampling event, the maximum mass of clam tissue data collected at a given sampling location was only 217.57 grams. At 18 g/day, this location would be depleted of clam tissue within 13 days. However, following EPA direction, bivalve consumption is treated as a potential future exposure pathway at the rates used in the BHHRA.~~

~~Most of the uncertainties associated with the fish and shellfish exposure parameters provide a conservative estimate of the risks associated with fish and shellfish consumption. Because noncancer hazards and cancer risks associated with consumption of fish and shellfish exceeded the NCP target noncancer hazard quotient of one and the cancer risk range of 1 x x 10^{-4} to 1 x x 10^{-6} as well as the point of departure of 1 x x 10^{-6}, the uncertainties associated with fish and shellfish consumption could affect the decisions made in the FS.~~ The upper and lower bounds ~~magnitude~~ of uncertainty ~~associated with exposure parameters for~~ relating to ~~tissue~~ fish the shellfish consumption ~~ingestion scenarios was estimated for the BHHRA based on the data presented above, and~~ is discussed in Attachment F6.

~~7.2.5.4~~6.2.4.4 Assumptions about a Multi-Species Diet

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Uncertainties exist in the assumptions about the relative composition of a multi-species diet ~~composition.~~ . The non-tribal multi-species diet assumes equal proportions of all four resident fish species~~. The~~, the tribal multi-species diet ~~consists~~ assumed ~~of~~ equal proportions of the four resident fish species, as well as dietary percentages of salmon, lamprey, and sturgeon ~~that come~~derived from the CRITFC ~~Fish Consumption s~~Survey ~~(CRITFC 1994).~~ . Variations of these dietary assumptions ~~from these compositions~~ would result in different risk estimates~~. ~~. Because the risks from consumption of the individual species that make up the multi-species diet were evaluated separately, the range of risks from fish consumption scenarios encompasses the potential variations in the multi-species diet~~. ~~. The range of the magnitude of these risks ~~was between 1 and 8~~generally less than an order of magnitude, and is discussed further ~~. The derivation of these risk ranges is further discussed~~ in Attachment F6~~.~~. The magnitude in the difference of risk estimates based on diet composition shows that this uncertainty could result in over or under-estimation of actual risks from a multi-species diet.

~~7.2.6~~6.2.5 Exposure Point Concentrations

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~~The EPC is supposed to represent the arithmetic average of the concentration of a contaminant that will be contacted over the exposure duration; however, as a protective approach, a UCL on the arithmetic average is recommended for use as the EPC (EPA 1989). Given the uncertainties and variability associated with environmental data, a high amount of uncertainty is associated with calculating a representative EPC.~~ The following ~~EPC~~ uncertainties ~~have been identified~~related to calculation of~~-~~ EPCs ~~and~~ for this risk assessment were analyzed further ~~in the BHHRA~~ to determine the potential effects on the risk estimates.

~~7.2.6.1~~6.2.5.1 Using 5-10 Samples to Calculate the 95~~%~~ percent UCL on the Mean

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Data sets with fewer than 10 samples per exposure area generally provide poor estimates of the mean concentration, defined as a large difference between the sample mean and the 95 percent UCL~~.~~. In general, the UCL approaches the true mean as more samples are included in the calculation~~Using less than ten sample results to calculate a 95%~~ percent ~~UCL on the mean increases the uncertainty associated with the 95%~~ percent ~~UCL for certain calculation methods. EPCs for a number of exposure areas throughout the Study Area were based upon the 95%~~ percent ~~UCL on the mean concentration calculated using less than 10 samples. These EPCs are discussed and listed in Attachment F2 text and tables. They include EPCs for in-water sediment, surface water, and tissue. Calculating the 95%~~ percent ~~UCL on the mean using less than 10 samples could overestimate or underestimate actual exposures.~~ The Study Area-wide fish tissue EPCs that were calculated as 95~~%~~ percent UCL on the mean~~ concentrations,~~ using less than 10 samples, included ~~the Study Area-wide~~ EPCs for whole body brown bullhead and fillet common carp~~.~~. The ~~maximum~~ EPCs for the individual exposure points for whole body brown bullhead and fillet common carp were up to two times higher than the Study Area-wide EPCs, as discussed in Attachment F6.

~~9.0 If maximum detected concentrations had been used as EPCs in place of 95%~~ percent ~~UCL on the mean concentrations for exposure areas with less than 10 samples, exposures would have likely resulted in an overestimate of actual risks.~~

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~~7.2.6.2~~6.2.5.2 Nondetects Greater than Maximum Detected Concentrations

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Consistent with EPA guidance, ~~Individual non-detected~~ analytical results reported as non-detect for which the detection limit was greater than the maximum detected concentration in a given exposure area were removed from the dataset prior to calculation of the 95~~%~~ percent UCL ~~calculations.~~ . These sample identifications, detection limits, and associated maximum concentrations are ~~discussed and~~ listed by media and exposure area in ~~in~~ the tables in Attachment F2 ~~text and tables~~. ~~A nondetect concentration means the actual concentration of the chemical could be as high as the detection limit, or it could be not present. However, if a detection limit exceeds the maximum detected concentration in a given exposure area, it is unknown whether the actual concentration is closer to zero or closer to the detection limit. Removal of these data prior to 95% percent UCL calculations decreases the need for assumptions about what the actual concentration may be, but it also decreases overall sample size for a given chemical and exposure area.~~

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~~As discussed in Section 5.2.5, PCBs are the primary contributor to the cumulative risks for all of the fish tissue consumption scenarios, and dioxins are the secondary contributor. There were no cases for which nondetect concentrations exceeded the maximum detected concentration of PCBs and dioxins in fish tissue. It follows that the cases where nondetect concentrations exceeded the maximum detected concentrations did not impact the cumulative risk estimates. PCBs and dioxins were also the primary contributor to cumulative risk for shellfish tissue consumption and there were no cases where nondetect concentrations exceeded the maximum detected concentration of PCBs and dioxins in shellfish tissue. For surface water and in-water sediment the ratio of the nondetect concentrations exceeding the maximum detected concentrations were within two orders of magnitude.~~ If the actual concentrations were closer to the detection limit for surface water and in-water sediment, the risk estimates would still be less than 1 ~~x~~ x 10^{-6}.

~~7.2.6.3~~6.2.5.3 Using the Maximum Concentration to Represent Exposure

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The maximum concentration was used ~~For cases~~in instances ~~with~~ where there were either less than five detected ~~samples~~ results or fives samples for a given analyte and exposure area~~, the sample size was not sufficient to calculate a 95% percent UCL on the mean concentration for an EPC, and the maximum concentration was used. This,~~ including ~~es~~ EPCs calculated to represent Study Area-wide exposure~~.~~ . ~~Using maximum detected concentrations of infrequently detected contaminants to represent individual exposure areas, and especially Study Area-wide exposure, results in an extremely conservative estimate of risk for the Study Area. In general, use of 95% percent UCL on the mean concentrations or maximum concentrations provided a protective approach and likely resulted in overestimates of the actual risks, especially for ongoing, repeated, long-term exposures.~~ Use of the maximum concentration to represent exposure occurred for all media, and occurred most frequently for the fish and shellfish consumption scenarios~~.~~ . Contaminants and exposure points for which the maximum detected concentration was used instead of a 95~~%~~ percent UCL on the mean are presented in the exposure point concentration tables in Section 3~~.~~ . In some cases, the maximum concentration for a contaminant was anomalously high, and may not be representative of tissue concentrations resulting from exposure to CERCLA-related contamination within the Study Area.

Generally, the ratios between the maximum and minimum detected concentrations are less than 3~~.~~ . For in-water sediments, the ratios are less than 4~~.~~ . When comparisons are made within an exposure area for biota, the majority of the ratios of the 95~~%~~ percent UCL/maximum EPCs to the mean are equal to or less than 2, and the remaining ratios are less than 4~~.~~ . A more in-depth analysis of scenarios for which using the maximum concentration to represent exposure significantly affected the result of the risk estimate, and consequently which chemicals were designated as contaminants potentially posing unacceptable risks for a scenario, is provided in Attachment F6.

EPA's UCL guidance (EPA 2002) notes that that defaulting to the maximum observed concentration may not be protective when sample sizes are very small because the observed maximum may be smaller than the population mean~~The conservatism of using the maximum detected concentration as the EPC for exposure areas with less than 5 detected results impacts the conclusions of this BHHRA~~.

~~7.2.6.4~~6.2.5.4 Possible Effects of Preparation and Cooking Methods

Cooking and preparation methods of fish tissue can ~~modify the amount of contaminant ingested by fish consumers~~change the concentration of lipophilic contaminants in fish tissues;~~.~~ ~~The~~ EPA (1997b) states that "cleaning and cooking techniques may reduce the levels of some chemical pollutants in the fish." ~~.~~ PCBs~~, which were found to have the greatest contribution to the cumulative cancer risks and the highest noncancer HQs,~~ tend to concentrate in fatty tissues~~.~~ . T~~herefore, t~~rimming away fatty tissues, including the skin, may reduce the exposure to PCBs~~.~~ . Removing the skin can reduce ~~The~~ PCB concentrations ~~of PCBs~~ in raw fillet ~~tissue have been shown to decrease~~ by ~~approximately~~ 50~~%~~ percent by ~~removing the skin~~ (EPA 2000c)~~.~~ . Cooking can also reduce the concentrations ~~of PCBs up to~~as much as 87~~%~~ percent, depending on the method (Wilson et al. 1998)~~.~~ . However, one study showed a net gain in PCB concentrations after cooking (EPA 2000c)~~.~~ . The potential for reduction in PCB concentrations due to cooking is subject to a substantial degree of variability, and some consumption practices make use of whole fish, reductions in PCB concentrations were not considered quantitatively in the risk assessment

~~As per EPA directive, dose modifications to account for cooking or tissue preparation were not used in determining EPCs for fish ingestion. If included, the risk estimates may have been reduced by up to approximately 90%~~ percent ~~for some contaminants. Since PCBs contribute to the majority of risks from fish consumption, this uncertainty could significantly impact the results of this BHHRA. For other contaminants, particularly mercury, which accumulates in the muscle tissue of fish, cooking is not known to reduce the concentrations in tissue; however, mercury does not contribute to the cumulative cancer risks.~~ .

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~~7.2.6.5~~6.2.5.5 Assumptions about Arsenic Speciation

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The ~~EPA~~ toxicity ~~data represent inorganic~~of arsenic is dependent on the chemical species, inorganic arsenic~~.~~ Is generally more toxic than organic forms~~.~~. ~~\and~~ ~~T~~tissue concentrations of ~~Arsenic~~ arsenic ~~in tissue was analyzed~~~~are~~were reported ~~only~~ as total arsenic, which is consistent with EPA toxicity criteria, which are based on total arsenic~~.~~. A study conducted on the middle ~~Toxicity data are only available for inorganic arsenic.~~ Willamette River (EVS 2000) measured composites of resident fish (largescale sucker, carp, smallmouth bass, and northern pikeminnow) from a 45-mile section of the iver extending from the Willamette (River Mile 26.5) to Wheatland Ferry (River Mile 72). Total arsenic and inorganic arsenic concentrations were determined in composites of whole body, fillet with skin, and composites of that portion of the fish remaining after removing fillets~~.~~. Percent inorganic arsenic ranged from 2 percent (carp) to 13.3 percent (sucker)~~.~~. The average percent of inorganic arsenic was 4.2 percent for the carp and 3.8 percent for the smallmouth bass. ~~The Columbia River Basin Fish Contaminant Survey (EPA 2002e) determined that a "value of 10% percent is expected to result in a health protective estimate of the potential health effects from arsenic in fish". Therefore,~~Consistent with the recommendation in the Columbia River Basin Fish Contaminant Survey (EPA 2002e), the EPC for inorganic arsenic was estimated as 10~~%~~ percent of the total arsenic detected in tissue~~.~~. ~~In previous fish tissue studies in the lower Columbia and Willamette Rivers, the percent of inorganic arsenic relative to total arsenic ranged from 0.1% percent to 26.6% percent with an average percent inorganic arsenic of 5.3% percent in the resident fish samples from the Willamette River (Tetra Tech 1995, EVS 2000).~~

~~In clams~~I~~, i~~norganic arsenic in clams was found to range as high as 50~~%~~ percent of total arsenic in ~~tissue~~ data collected in the Lower Duwamish River~~.~~. However, ~~the~~ the Lower Duwamish ~~River~~ is an estuarine system, ~~ry~~ while the Lower Willamette in Portland Harbor is ~~a~~ freshwater ~~river, .~~. ~~so the species of clams in the Duwamish River are different from those in Portland Harbor.~~ Since the actual percent of arsenic that is inorganic in clam tissue from the Study Area is unknown, this results in uncertainty in the estimate of inorganic arsenic EPCs ~~for~~ in shellfish~~clam~~. The clam tissue data collected from the Study Area ~~in Rounds 1 through 3~~ was evaluated to determine whether a higher percentage of inorganic arsenic might have a significant effect on overall risk from the consumption of clam tissue:~~. The analysis found:~~

- All of the arsenic concentrations in clam tissue are within a factor of 2~~.~~. ~~of each other (i.e., the maximum concentration is approximately 2 times higher than the minimum concentration).~~ In addition, the arsenic concentrations in clams are normally distributed~~.~~. ~~Both of these facts support the conclusion that the arsenic in clams is due to ubiquitous concentrations, not localized sources.~~
- Due to the narrow range of arsenic concentrations, the risks from consumption of clams are within a factor of 2 throughout the Study Area.

- If inorganic arsenic is assumed to be 50~~%~~ percent of the total arsenic rather than the assumption of 10~~%~~ percent used in the BHHRA, the cumulative risks from consumption of clams ~~only~~ increase by a factor of 1.1 to 1.3~~.~~. Arsenic is not the ~~because there are other contaminants that are~~ primary contributor~~s~~ to risks from consumption of clams.

Given all of the other uncertainties associated with risks from clam consumption, the inorganic arsenic assumption is a minor uncertainty with minimal effect on the overall risk estimates.

Although arsenic resulted in risks greater than 1 ~~x~~ x 10^{-6} for some of the fish consumption scenarios, the contribution of arsenic to the cumulative risk was ~~insignificant relative~~substantially less than ~~to~~ that from PCBs~~.~~. Therefore, the assumptions about inorganic arsenic are not likely to ~~impact~~ affect the overall ~~the~~ conclusions of ~~this~~ the BHHRA~~.~~.

~~7.2.6.6~~6.2.5.6 Polychlorinated Biphenyls

PCBs were analyzed as Aroclors in some media and as individual PCB congeners in others~~.~~. This introduces some uncertainty when comparing cumulative risk across media. Congener analysis may provide a more accurate measure of PCBs in environmental samples than does the Aroclor analysis~~.~~. Although most PCBs may have originally entered the environment as technical Aroclor mixtures, environmental processes, such as weathering and bioaccumulation, may have led to changes in the congener distributions in environmental media such that they no longer closely match the technical Aroclor mixtures used as standards in the laboratory analysis, leading to inaccuracies in quantitation~~.~~.

The results for PCBs in whole body tissue samples analyzed for both PCBs as Aroclors and as individual PCB congeners were qualitatively compared to evaluate correlations associated with the use of Aroclor data. Windward (2005) analyzed fish tissue from the Lower Duwamish Waterway as PCB Aroclors and as individual PCB congeners~~.~~. The PCB Aroclor data and PCB congener data were significantly correlated for both fillet and whole body tissue~~.~~. It should be noted that the Lower Duwamish Waterway is not freshwater, and different species were assessed in the Lower Duwamish study compared to Portland Harbor~~.~~. The~~r~~se ~~is less uncertainty associated with using PCB congener data to calculate EPCs; however, these~~ correlations suggest that PCB Aroclor data may be used in the place of congener data if congener data are not available.

When available, PCB congener data were included in cumulative risk sums for tissue because differences in bioaccumulation, in addition to weathering~~,~~ results in ~~even~~ greater uncertainty in the PCB Aroclor analysis for tissue~~.~~. However, ~~for~~ fillet tissue collected in~~,~~ Round 1 ~~samples were~~was analyzed for PCB Aroclors only, ~~and~~ Round 3 smallmouth bass and common carp samples~~, which were collected for smallmouth bass and common carp, were~~ were analyzed for PCB congeners only~~.~~. Because PCB

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congener data are available for smallmouth bass and common carp fillet tissue, cumulative risks for exposure to fillet tissue from ingestion include only the most recent tissue data for these two species. This introduces uncertainty to the cumulative risk estimates for exposure to fillet tissue when comparing risks across all four resident species.

PCB Aroclor data were included in cumulative risk sums for sediment because the PCB Aroclor dataset is larger than the congener dataset~~. ~~.

PCB congener data were included in the risk evaluation for surface water because the PCB Aroclor data was derived from the results of the congener analysis for the samples used in the risk characterization of this BHHRA~~. ~~. Total PCB congeners did not screen in as COPCs for any surface water scenarios~~. ~~. If PCB Aroclor data from the surface water dataset were used in the COPC screening, PCBs would still not be considered a COPC for any surface water scenarios.

When PCB congener data were used, the total PCB concentration was adjusted by subtracting the concentrations of coplanar PCBs from the total PCB concentration~~. ~~. This was done for purposes of estimating cancer risks because the coplanar PCBs were evaluated separately for the cancer endpoint~~. ~~.

~~7.2.6.7~~6.2.5.7 Bioavailability of Chemicals

The toxicity values used in the risk assessment are ~~generally~~ often based on laboratory studies in which the chemical is administered in a controlled setting via food or water~~. ~~. A~~The actual a~~bsorption from environmental media may be lower than that observed in the laboratory~~. ~~. Studies have shown that conditions in environmental media (e.g., pH, organic carbon content) can affect the bioavailability of a chemical (Ruby et al. 1999, Pu et al. 2003, Saghir et al. 2007)~~. ~~. If the bioavailability of a chemical in a given environmental medium is less than that in the laboratory study used to derive the toxicity value, the risk assessment will overestimate the ~~risks associated with~~ exposure to that chemical in that medium~~. ~~. T~~A committee of t~~he National Research Council has recommended that consideration of bioavailability be incorporated in decision-making at sites (National Academy of Sciences 2003)~~. ~~. While site-specific information on the bioavailability of chemicals in sediment is not available, it is important to recognize that there is uncertainty associated with not incorporating bioavailability into the risk estimates, especially related to sediment-associated chemicals.

~~7.2.6.8~~6.2.5.8 Exposure Areas for Consumption of Smallmouth Bass ~~Exposure Areas~~

Exposure via consumption of ~~Smallmouth~~ smallmouth bass ~~exposure areas were~~was evaluated on a river mile basis~~. ~~. Uncertainties associated with the home range of smallmouth bass are discussed in Section 6.1.13~~. ~~. In Round 1, samples were composited on a per river mile basis~~ (e.g., RM 2, RM 3). In ~~. Round 3, samples were

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composited on a per river mile basis~~, per~~ for each side of river~~ (e.g., RM 2E, RM 2W). ~~. The Round 1 and Round 3 results were combined, and ~~included in~~ the EPC ~~calculations for each~~thus represents an -exposure area of one river mile~~ exposure area.~~ . ~~Although studies have shown that smallmouth bass migrate from one side of the river to another in the lower~~ A study by ODFW (ODFW 2005) that included tracking the movement of smallmouth bass in the Lower Willamette indicated that their home range is typically between 0.1 and 1.2 km, and they are most frequently found in near-shore areas~~. ~~. ~~(ODFW 2005), it is possible that some smallmouth bass may have a home range that is limited to a single side of the river.~~

Figure 6-1 displays the ratios of concentrations of DDT, DDE, DDD, cPAH, dioxin/furan TEQ, and PCB congeners detected in composite smallmouth bass samples collected at the east side of the river mile compared to concentrations for those detected in composite samples collected at the west side of the river mile~~. ~~. At ~~RM~~ RM 8, 9, and 10, the ratios are all less than 1, indicating concentrations on the east side of the river are generally less than concentrations on the west side of the river~~. ~~. For the remaining river miles, some ratios exceed one~~. ~~. East to west side concentration ratios for PCBs at river mile 11 are highest of any river mile evaluated~~.~~ . ~~–~~ A~~It should be noted, a~~s previously discussed in Section 6.1.14, that a fish from ~~RM~~ RM 11W was included in the composite for ~~RM~~ RM 11E due to a mislabeling of the sample~~. ~~. Due to the low number of samples for each exposure area, the maximum detected concentration from either side of the river was typically ~~is almost always~~ used as the ~~95% percent UCL/max~~RME EPC for the river mile exposure areas ~~anyway, which eliminates the possibility of underestimating risk for a given river mile based on whether or not smallmouth bass migrate across the river. ~~. ~~Furthermore, the river mile exposure area was determined based on the smallmouth bass home range.~~ In addition, the area over which fishing occurs should also be considered~~. ~~. Given ~~the~~ an exposure duration of 30 to 70 years, it is ~~likely~~ possible that fish would be collected over an area greater than a single river mile~~ for localized exposures~~. Therefore, ~~the characterization of risk for~~use of an exposure area consisting of a single river mile for evaluating consumption of smallmouth bass ~~in this risk assessment~~ is generally ~~a~~ health protective ~~estimate that is~~and unlikely to underestimate risks.

~~7.2.6.9~~6.2.5.9 EPCs in Surface Water ~~EPCs~~ for Recreational Beach Users

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Only data collected from the low water sampling event was used to assess~~For~~ recreational exposures to surface water, ~~data from only the low water sampling event was used,~~ in order to represent surface water conditions during the time of year when most frequent recreational use occurs~~ (i.e. summer months). ~~. There is some uncertainty in the representativeness of this dataset for surface water conditions for recreational users.

Because ~~Transient~~ exposure to surface water by transients can occur throughout the year, ~~so~~ data from sampling events during three seasons of the year were used for this scenario and can be used to assess the representativeness of the single low water sampling event. Arsenic was the only surface water COPC detected in recreational exposure areas. The Study Area-wide average total arsenic concentration for transient exposure to surface water, using year-round data, is 0.48 µg/l. The Study Area-wide average total arsenic concentration for recreational beach user exposure to surface water, using low flow data, is 0.51 µg/l. Given the similarity of these results, the uncertainty associated with the recreational beach user surface water dataset should not affect ~~impact~~ the conclusions of this BHHRA.

~~7.3~~6.3 TOXICITY ASSESSMENT

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The results of animal studies are often used to predict the potential human health effects of a chemical. Extrapolation of toxicological data from animal studies to humans is one of the largest sources of uncertainty in evaluating toxicity ~~factors.~~. Much of the toxicity information used in this BHHRA comes from EPA's Integrated Risk Information System (IRIS), which states the following on its website:

> In general IRIS values cannot be validly used to accurately predict the incidence of human disease or the type of effects that chemical exposures have on humans. This is due to the numerous uncertainties involved in risk assessment, including those associated with extrapolations from animal data to humans and from high experimental doses to lower environmental exposures. The organs affected and the type of adverse effect resulting from chemical exposure may differ between study animals and humans. In addition, many factors besides exposure to a chemical influence the occurrence and extent of human disease (EPA 2010b, http://www.epa.gov/iris/limits.htm).

EPA typically applies uncertainty factors, typically a factor 10, when deriving reference doses, to account for limitations in the data. ~~Because of these uncertainties, toxicological data parameters are usually conservative to be more protective of human health due to safety factors EPA uses when estimating toxicity values. The safety factors used by EPA typically range from two to three orders of magnitude (100 to 1,000 times), depending on various aspects of the animal study.~~ These limitations include variation in susceptibility among the members of the human population, uncertainty in extrapolating animal data to humans, uncertainty in extrapolating from data obtained in a study with less-than-lifetime exposure, uncertainty in extrapolating from a LOAEL rather than from a NOAEL, and uncertainty associated with extrapolation when the database is incomplete. As a result, actual risks within the Study Area ~~could~~ are likely to be lower than the ~~potential risk~~ estimates calculated in this BHHRA.

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~~In~~ In addition ~~to the uncertainty already included in the toxicity values~~, the following specific uncertainties ~~the following toxicity value uncertainties~~ have been identified.

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~~7.3.1~~6.3.1 Early Life Exposure to Carcinogens

~~In 2005, EPA finalized the~~ As discussed in Section 3.5.6, early-in-life susceptibility to carcinogens has long been recognized as a public health concern~~.~~. EPA's Supplemental Guidance for Assessing Susceptibility from Early-Life Exposure to Carcinogens (EPA 2005b) ~~Supplemental Guidance for Assessing Susceptibility from Early-Life Exposure to Carcinogens (EPA 2005b). The guidance~~ provides a process to evaluate risks from early-life exposure to carcinogens ~~with~~ known to act via a mutagenic mode of action~~.~~. The only exposure scenarios ~~with~~ for which early-life exposures ~~(i.e., child populations)~~ are considered are recreational beach use~~rs~~, ~~and~~ fish consumption, and household use of surface water~~.~~. ~~Of these, the only scenario with potential exposure to chemicals with a mutagenic mode of action is the recreational beach user scenario for exposure to PAHs.~~Of the COPCs identified in the risk assessment, only cPAHs have been identified as mutagenic~~.~~.

~~This~~The BHHRA did not ~~evaluate risks using the new EPA guidance as the exposure factors~~specifically address early-life exposures ~~for the specific age classes~~ in the separate child and adult scenarios~~.~~. However, ~~the guidance~~increased early-life susceptibility was used to assess risks associated with exposure to PAHs in the combined adult/child scenarios. Therefore, the combined adult/child scenario accounts for the additional potency associated with early life exposures.

~~7.3.2~~6.3.2 Lack of Toxicity Values for Delta-hexachlorocyclohexane, Thallium, and Titanium

Delta-HCH was detected in tissue and in-water sediment~~.~~. An SF or RfD toxicity value could not be identified for delta-HCH according to the hierarchy of sources of toxicity values recommended for use at Superfund sites (EPA 2003b)~~.~~. Also, an STSC review concluded that the other hexachlorocyclohexane isomers could not be used as surrogates for delta-HCH due to differences in toxicity (EPA 2002d)~~.~~. Potential risk from delta-HCH was not quantitatively evaluated because of the lack of availability of toxicity data ~~for the chemical~~.

Thallium was detected in in-water sediment and surface water, and titanium was detected in in-water sediment~~.~~. Thallium and titanium are naturally occurring elements, and although thallium may have a wide spectrum of effects on humans and animals (EPA 2009a), titanium has been characterized as having extremely low toxicity (Friberg et al 1986)~~.~~. An SF or RfD toxicity value could not be identified for titanium according to the hierarchy of sources of toxicity values recommended for use at Superfund sites (EPA 2003b), and consultation with EPA indicated no surrogate toxicity value was available~~.~~. Therefore potential risk from exposure to titanium was not quantitatively evaluated in this BHHRA.

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~~7.3.3~~6.3.3 Use of Toxicity Values From Surrogate Chemicals for Some Chemicals that Lack Toxicity Values

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For some chemicals, if a RfD or SF toxicity value was not available from the recommended hierarchy, a structurally similar chemical was identified as a surrogate~~.~~. The RfD or SF for the surrogate was selected as the toxicity value and the surrogate chemical was indicated in Section 4~~.~~. Uncertainty exists in using surrogate chemicals to represent the toxicity of chemicals for which toxicity values are not available~~.~~. Using surrogate toxicity values could over- or under-estimate risk for a specific chemical.

Based on the results of the BHHRA, the chemicals that exceeded the minimum target cancer risks of 1 ~~x~~ x 10^{-6} or hazard quotient of 1 did not rely on surrogate toxicity values~~.~~. Therefore, the use of surrogate toxicity values should not ~~impact~~ affect the conclusions of this BHHRA.

~~7.3.4~~6.3.4 Toxicity Values for Chromium

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Chromium was analyzed as total chromium in all media~~.~~. Although toxicity values exist for both trivalent and hexavalent chromium, hexavalent chromium exhibits greater toxicity that the trivalent form~~Toxicity values exist for trivalent and hexavalent chromium only.~~. ~~A~~ The reference dose for hexavalent chromium is 0.003 mg/kg-day, versus 1.5 mg/kg-day for trivalent chromium~~, which is a factor of 500 times higher.~~. ~~The toxicity values for trivalent chromium were used in the toxicity assessment for the Study Area because~~ H~~h~~exavalent chromium ~~reduces~~ can be reduced to trivalent chromium in an aqueous environmental medium if an appropriate reducing agent is available, and thus trivalent chromium is more prevalent in the environment (ATSDR 2008)~~.~~. S~~Likewise, s~~creening values for trivalent chromium were used in the selection of total chromium as a COPC for in-water sediment, beach sediment, the groundwater seep, and surface water. This is an uncertainty because the trivalent chromium screening level is for insoluble salts.

The highest HQ for chromium ~~For~~ from fish consumption~~, the highest HQ from chromium~~ was 0.004. ~~,~~ E~~so e~~ven if a portion of the chromium were present as hexavalent chromium, the HQ would likely still be less than 1~~.~~. ~~Therefore, use of toxicity values for trivalent chromium should not impact the conclusions of this BHHRA~~A~~.~~

~~A~~dditionally, ~~that~~ EPA currently considers the carcinogenic potential of hexavalent chromium via oral exposure as "cannot be determined."~~ ~~ Toxicity criteria derived by the New Jersey Dept. of Environmental Protection ~~A~~ was used as a Tier 3 source ~~of toxicity criteria, the New Jersey Dept. of Environmental Protection, has derived quantitative dose-response criteria~~ for evaluating the cancer risks associated with oral exposures to hexavalent chromium~~, which is the value used in the BHHRA~~.

~~7.3.5~~6.3.5 Toxicity Values for Polychlorinated Biphenyls and Applicability to Environmental Data

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The toxicity values for PCBs were applied to both PCB congeners (not including coplanar congeners) and Aroclors~~. ~~. The RfD for PCBs is based on an immunotoxicity endpoint for Aroclor 1254 (EPA 2010b)~~. ~~. Several other Aroclors have been detected in media within the Study Area, indicating the mixture of PCBs differs from that used in the study to develop the RfD~~. ~~. The cancer SF for PCBs was derived for PCB mixtures based on administered doses of Aroclors to rats~~. ~~. The PCB mixtures used in the studies included the coplanar PCB congeners (~~i.e.,~~ dioxin-like PCBs), and ~~. These~~ coplanar PCBs may have contributed ~~significantly~~ to the carcinogenicity observed in the study~~. ~~. ~~The~~ Because the cancer risk from coplanar PCB congeners was evaluated separately, ~~so~~ including both the total PCB and coplanar PCB congener risks in the cumulative cancer risk ~~results~~ may result in an overestimate of the cancer risks~~. ~~. Although the potential double counting of PCB mass was corrected for ~~in~~ by using the PCB adjusted values ~~(mass of dioxin-like PCB was subtracted)~~, there was no correction for the potential double counting of toxicity of dioxin-like PCBs in the PCB TEQ cancer risk estimate ~~and as part of the PCB adjusted value cancer risk estimate~~.

~~Based on the dose-response data from studies in rats,~~ PCBs are classified as probable human carcinogens based on adequate dose-response data from studies in rats~~. ~~. However, the human carcinogenicity data are inadequate ~~for classification of PCBs as human carcinogens~~. Several cohort studies have been conducted that analyzed cancer mortality in workers exposed to PCBs. These studies did not find a conclusive association between PCB exposure and cancer; however they were limited by small sample sizes, brief follow-up periods, and confounding exposures to other potential carcinogens~~. ~~. Therefore, using a cancer SF based on the dose-response observed in rats adds further uncertainties to the cancer risk estimates from PCBs as a dose-response has not been observed in humans.

In addition to the uncertainties with toxicity values for total PCBs, there are uncertainties with the toxicity values for the PCB TEQ, which is evaluated using toxicity values for dioxin and dioxin-like compounds ~~(e.g., dioxin-like PCBs). ~~. In ~~their~~ its 2001 evaluation of the ~~EPA~~ dioxin reassessment, members of the EPA's Science Advisory Board (SAB) did not reach consensus on the classification of 2,3,7,8-TCDD as a carcinogen (EPA 2001d)~~. ~~. The National Academy of Sciences (NAS 2006) discussed the primary uncertainties with the toxicity values for dioxin and dioxin-like compounds as follows:

- The estimation of risks at doses below the range of existing reliable data may result in an overestimate of risk~~. ~~. An estimate of risk for typical human exposures to dioxin and dioxin like compounds would be lower in a sub-linear extrapolation model than in the linear model that was used to derive the 2,3,7,8-TCDD SF.

- The issue of appropriately assessing the toxicity of various mixtures of these compounds in the environment~~—~~. The relative concentrations may change over an exposure period, even though the potency of the individual congeners remains constant~~—~~. The estimated risk in a given sample depends on both potency and concentration.

The above uncertainties apply to risks from dioxins and furans, as well as risks from dioxin-like PCBs.

~~7.3.6~~6.3.6 Adjustment of Oral Toxicity Values for Dermal Absorption

As discussed in Section 4.7, an adjustment was applied to the oral toxicity factor to account for the estimated absorbed dose ~~To evaluate~~when evaluating dermal exposures~~ in this BHHRA, an adjustment to the oral toxicity factor to account for the estimated absorbed dose was applied, as discussed in Section 4.7 of this BHHRA~~ ~~.~~

~~As recommended by EPA guidance (EPA 2004), an adjustment to the oral toxicity factor to account for the estimated absorbed dose was applied in this BHHRA~~ when the following conditions ~~are~~ were met:

- The toxicity value derived from the critical study is based on an administered dose (e.g., through diet or by gavage)
- A scientifically defensible database demonstrates the GI absorption of the chemical is less than 50~~%~~ percent in a medium similar to the one used in the critical study.

~~If both conditions are not met, then a default oral absorption value of 100% percent is used so that no adjustment for GI absorption is made to evaluate toxicity from dermal exposures.~~

~~The~~ EPA (2004) recommends the adjustment of oral toxicity values to reflect dermal absorption ~~using a cutoff value of 50% percent GI absorption to reflect the intrinsic variability in the analysis of the absorption studies~~only when GI absorption was less than 50 percent, e~~. The cutoff value of 50% percent GI absorption obviates~~ liminating the need for small adjustments in the oral toxicity value that are not supported by the level of accuracy in the critical studies that are the source of the toxicity values~~—~~.

~~The EPA (2004) guidance states that scientific literature indicates that o~~Organic chemicals are generally well absorbed across the GI tract, absorption of ~~. For~~ inorganic chemicals ~~, the literature indicates a wide range of GI absorption values~~is dependent on a number of factors, but is generally less than for organic chemicals~~—~~. However, ~~if EPA (2004) guidance does not provide a GI absorption value for an inorganic COPC,~~in the absence of a specific value for GI absorption, ~~then the~~ a default ~~GI absorption value~~ of 100~~%~~ percent was used~~—~~. ~~The~~ EPA ~~(~~2004 ~~) guidance~~

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states that ~~this assumption of~~assuming 100~~%~~ percent absorption may ~~contribute to~~ underestimat~~eion of~~ dermal risk for those ~~inorganics~~ chemicals that are poorly absorbed because it overestimates the dose at the site of action~~.~~. T~~. T~~he extent of ~~this~~ underestimation is proportional to the actual GI absorption~~, which would not exceed 50% percent.~~. I~~The i~~norganic COPCs for which the default value of 100~~%~~ percent GI absorption was used~~-~~ are~~includes the following metals :~~aluminum, arsenic, boron, cobalt, copper, iron, molybdenum, selenium, thallium, and zinc~~.~~.

~~7.4~~6.4 RISK CHARACTERIZATION

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Uncertainties arise during risk characterization due to the methods used in calculating, summing, and presenting risks~~.~~. The following subsections address uncertainties associated with the risk characterization of this BHHRA.

~~7.4.1~~6.4.1 Endpoint-specific Hazard Indices

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In deriving endpoint-specific HIs, only one health endpoint is used for each chemical, even though ~~most~~ some chemicals may have a myriad of health effects as exposures increase~~.~~. As an example, a majority of the non-cancer ~~impacts~~ affect from the site are from PCBs and total TEQ. The endpoint used for deriving the RfD for PCBs is immunotoxicity, while the endpoint used for deriving the RfD for dioxin/furan TEQ and PCB TEQs is ~~reproduction~~reproductive effects~~.~~. If the reproductive endpoint for PCBs based upon the lowest observed adverse effects level (LOAEL) of 0.02 mg/kg/day is used with the same Uncertainty Factor as the immunological endpoint to derive an RfD for a reproduction endpoint for PCBs, the RfD for reproductive effects ~~will~~ would be ~~4 ti~~a factor of 4 greater ~~mes~~ than the RfD for immunological effects~~.~~. Using this ratio, the endpoint-specific HI for reproduction for this exposure scenario for PCBs would be 5,000/4 = 1,250. The total HI for reproduction effects, combining HIs for total TEQ (500) and non-dioxin-like PCBs (1,250), would increase from 500 to 1,750. For the chemicals that have the largest non-cancer contribution in the HHRA, there is a possibility of under-predicting non-cancer health effects by using only one endpoint per chemical.

~~7.4.2~~6.4.2 Risks from Cumulative or Overlapping Scenarios

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Where multiple exposure scenarios exist for a given population~~(i.e., recreational beach users are potentially exposed to both beach sediment and surface water)~~, the risks for each of the exposure scenarios that are considered potentially complete and significant for a given population were summed to estimate the cumulative risks for that population (see Tables 5-199 and 5-200)~~.~~. In calculating the cumulative risks, the maximum cancer risk for each RME scenario was used~~.~~. This provides a conservative approach, as the same individual may not ~~have~~ experience the maximum exposure under more than one exposure scenario~~.~~. However, due to the fact that risks from one scenario are usually orders of magnitude higher than any other scenario for a given receptor, risks from potential cumulative scenarios should not

~~impact~~ affect the conclusions of this BHHRA~~.~~ . However, the possible magnitude of uncertainty associated with risks from cumulative or overlapping scenarios is discussed further in Attachment F6.

In addition to cumulative exposure scenarios for a given population, an individual may be a member ~~part~~ of multiple exposure populations~~, (i.e., a dockside worker that is also a non-tribal fisher)~~ and thus ~~could have~~ overlapping exposure scenarios~~.~~ . Because there are numerous possible combinations of overlapping scenarios due to variations in exposure points and exposure assumptions, a model was not developed to quantitatively evaluate overlapping scenarios in this BHHRA~~.~~ . However, because the risk from ~~tissue ingestion~~fish and shellfish consumption is typically at least ~~10~~ 10-fold ~~times higher~~greater than other exposure pathways, if an individual consumes fish, the relative contribution from other exposure scenarios is not likely to contribute significantly to the overall risks for that individual~~.~~ . This BHHRA presents the risks for all of the exposure scenarios, so the risks for a given overlapping scenario could be calculated simply by summing the risks for each of the exposure scenarios that make up the overlapping scenario.

This BHHRA assessed potential risks from exposure to media within the Study Area~~.~~ . Upland sites were not included in this BHHRA~~.~~ . If exposure to upland sites were incorporated with exposures to media within the study, the overall estimate of cumulative risk would likely be higher than the risk estimates in this BHHRA.

~~7.4.3~~6.4.3 Risks from Background

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Metals are naturally occurring and may be present in tissue, water, or sediment may not be directly related to contamination~~.~~. Reported ~~Concentrations~~ concentrations of arsenic and mercury in samples collected within the Study Area ~~were found to~~ result in estimated risks greater than 1 ~~x~~ x 10^{-6} or an HQ of 1 for ~~at least~~ one or more of the exposure scenarios evaluated in ~~this~~ the BHHRA~~.~~ . ~~However, metals are naturally occurring chemicals and may be present in tissue, water or sediment due to background concentrations. For~~Exposure concentrations of arsenic in beach sediment~~, the exposure point concentrations~~ ranged from 0.~~7~~ 7 mg/kg to 9.9 mg/kg, within the general range of ~~and are consistent with the default background soil concentration for arsenic of~~ 7 mg/kg used as a background concentration of arsenic by DEQ (~~DEQ~~ DEQ 2007)~~.~~ . Risks from background concentrations of arsenic in beach sediment and surface water are discussed in Section 5 of ~~this~~ the BHHRA~~.~~ . ~~In addition to naturally occurring metals, anthropogenic background may contribute to the overall risks.~~

Neither ~~natural~~ background nor anthropogenic ~~background~~ tissue concentrations of COPCs were established for the Study Area~~. Natural and anthropogenic sources of both metals and organic chemicals are known to contribute to COC concentrations in abiotic media and biota in the Study Area.~~ .

~~Although background tissue concentrations for the Study Area were not established, in some cases, R~~Rregional tissue concentrations were ~~correspond to risk estimates above the target risk thresholds established by EPA (i.e. cancer risk of 10^{-6} to 10^{-4})[8].~~ ~~For example,~~measured ~~in~~ as part of the Columbia River Basin Fish Contaminant Survey~~, HIs were greater than 100 and cancer risks were as high as 2 x~~ ~~x~~ ~~10^{-2} for the highest tribal fish consumption rate (389 g/day) (EPA 2002c). In this study, the fish species collected included~~ in five anadromous species (Pacific lamprey, smelt, coho salmon, fall and spring Chinook salmon, steelhead) and six resident species (largescale sucker, bridgelip sucker, mountain whitefish, rainbow trout, white sturgeon, walleye)~~.~~. All samples were composites; the size of the individual fish varied with species~~.~~. C~~However, c~~oncentrations of certain contaminants are higher in tissue collected within the Study Area than observed in the ~~regional tissue~~Columbia River study, and the sources of the regional tissue concentrations are unknown~~, and regional efforts are underway to reduce contaminant concentrations in tissue.~~. ~~.~~

~~While~~Consistent with EPA policy, ~~risks~~ risk estimates were presented in this BHHRA without accounting for contributions from background~~, .~~. However, it is important to recognize that background concentrations may result in unacceptable ~~risks~~ risk and hazard estimates. ~~based on the exposure assumptions used in this BHHRA. The proportion of the concentrations that are not due to releases from sources in the Study Area cannot be controlled by remedial actions in the Study Area. This could prevent remedial actions in the Study Area from achieving acceptable risk levels.~~

~~7.4.4~~6.4.4 Risks from Lead Exposure

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T~~Because t~~he maximum EPC~~s~~ calculated for lead are ~~greater than the protective fish tissue concentrations~~ associated with ~~an acceptable~~a probability of exceeding protective blood lead levels in the fetus of a pregnant woman ~~ingesting tissue~~who consumes fish from the Study Area.~~,~~ ~~lead is considered a chemical potentially posing unacceptable risk for fish tissue.~~ T~~However, t~~his ~~maximum~~ EPC ~~is orders of magnitude greater than all other fish EPCs and~~ may be attributable to lead in the gut of the fish rather than tissue concentrations~~.~~.

Protective lead ~~tissue~~ concentrations in tissue were estimated using the EPA Adult Lead Methodology (ALM) (EPA 2003c), based on agreements with the EPA to follow the same methodology used in the CRITFC (1994) survey to assess tissue exposures from lead. The ALM as adapted for the Portland Harbor BHHRA focuses on potential ~~impacts~~ affects to the fetus ~~of a pregnant worker, and therefore, is only appropriate~~ when considering fish consumption by pregnant women~~.~~. However, t~~T~~he ALM was developed ~~based on~~ for evaluating exposure to lead in soil and may not be appropriate to use for fish consumption~~.~~. Furthermore, the ALM is ~~highly~~ sensitive to the bioavailability of ingested lead~~.~~. For purposes of ~~developing~~ calculating ~~the~~

~~[8] Regional tissue concentrations are discussed in the Risk Management Recommendations document for the Portland Harbor, provided by the LWG to EPA under separate cover.~~

~~protective~~a tissue ~~concentrations~~concentration of lead that is expected to be without adverse effects, the default bioavailability of lead in soil was used~~. It~~, and it is not known whether this is an appropriate assumption for lead in tissue.

~~10.0 While lead was identified as a contaminant potentially posing unacceptable risk for fish tissue, there is considerable uncertainty associated with that decision. The identification of lead as a contaminant potentially posing unacceptable risk was based on the maximum EPC, which may not be due to CERCLA activities, and is not representative of Study Area-wide lead concentrations. Furthermore, the identification of lead as a contaminant potentially posing unacceptable risk was based on the ALM, which was not developed for fish consumption.~~

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~~11.0 For in-water sediment, blood lead levels were also estimated using the ALM. As discussed above, the methodology focuses on potential impacts to the fetus of a pregnant worker, and therefore, is only appropriate when evaluating exposures by pregnant women. Because lead was not identified as a contaminant potentially posing unacceptable risk for in-water sediment, the use of the ALM to evaluate risks from lead exposure for in-water sediment is not likely to impact the conclusions of this BHHRA.~~

~~7.4.5~~6.4.5 Future Risks

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This BHHRA estimated current and future risks for exposure within the Study Area, based on known and reasonably ~~foreseeable~~ anticipated future uses of the Study Area~~.~~. ~~In addition, this BHHRA assessed hypothetical scenarios at EPA's request.~~ However, the LWR is a ~~highly~~ dynamic, industrialized water~~-~~way, and if the land uses in certain areas of the Study Area were to change in the future in a manner ~~that was not foreseen in~~with the uses considered in ~~this~~ the BHHRA, ~~the assumptions and scenarios used to evaluate risks for the Study Area may not be applicable to risks from new exposures~~risk and hazard estimates presented here may not be representative of conditions in the future~~.~~. ~~Nevertheless, due to the conservative nature of the assumptions used in this BHHRA, the risk estimates in this BHHRA may still be protective of future uses of the Study Area that were not evaluated. The uncertainty related to future risks could result in either higher or lower risk estimates for the Study Area.~~

~~7.5~~6.5 OVERALL ASSESSMENT OF UNCERTAINTY

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A summary of the uncertainties and a qualitative classification of their magnitude, their impact on the health protectiveness of the assessment, and their significance to risk management decisions are presented in Table 6-1~~.~~. For each of the uncertainties identified and discussed in this section, Table 6-1 provides a qualitative assessment (using High, Medium, and Low as descriptors) for each of these properties~~.~~. In addition, the table presents whether an uncertainty is more likely to over-estimate or under-estimate actual risks from the Study Area~~.~~. While there are numerous uncertainties identified for this BHHRA, and the cumulative effect of these uncertainties could be significant to the conclusions of the BHHRA, some of these uncertainties would be expected to have more of a significant effect on risk management decisions than other uncertainties. These are identified with a "High" descriptor under the "Significance to Risk Management" column in Table 6-1.

Risk assessments typically include conservative assumptions to minimize the chances of underestimating exposure and/or risks of adverse effects to human health, and therefore potentially underestimating the need for remedial actions. In this BHHRA, conservative assumptions were incorporated into the identification of exposure scenarios, the selection of exposure assumptions, the development of EPCs, and the use of toxicity values. Only a portion of the uncertainties in this BHHRA are quantifiable. Further analysis of the data and review of pertinent published literature provided a possible range of values for some of the uncertainties presented above. The magnitude of these ranges are provided in Attachment F6 and discussed in this Section.

While it is not probable that the maximum values of the uncertainties apply for every tissue consumption exposure scenario and contaminant , this magnitude of uncertainty indicates that risks may actually be less than 1 x 10^{-4} or HI of 1 for certain scenarios.

While conservative, the results of the BHHRA are intended to show the relative risks associated with the exposure scenarios, and which contaminants are contributing the highest percentage of the calculated risks.

~~8.0~~7.0 SUMMARY

The overall objective of this BHHRA ~~was to~~ is to provide an analysis of potential baseline risks to human health from site-related contaminants and help determine the need for remedial actions, provide a basis for determining contaminant concentrations that can remain onsite and still be protective of public health, and provide a basis for comparing the effectiveness of various remedial alternatives. ~~evaluate whether exposure to contaminants in sediment, surface water, groundwater seeps, or biota may result in unacceptable risks to human health. .The results of this BHHRA will be used in developing remedial action objectives and assist in risk management decisions for the Site. .The results of this BHHRA have been used in developing risk management recommendations for the Site, submitted to the EPA under separate cover.~~

The populations evaluated in ~~the risk characterization portion of~~ the BHHRA were identified based on human activities ~~that are~~currently known to occur within the Study Area ~~now and/~~or could ~~which could~~ occur in the future ~~within the Study Area~~, as described in the Programmatic Work Plan~~, or were directed by EPA for evaluation in this BHHRA. .~~ P~~The following are the p~~opulations and associated exposure scenarios that were quantitatively evaluated in this BHHRA include:

- Dockside Workers – Direct exposure to beach sediment
- In-water Workers – Direct exposure to in-water sediment
- Recreational Beach Users – Direct exposure to beach sediment and surface water
- Transients – Direct exposure to beach sediment, surface water, and groundwater seep
- Divers – Direct exposure to in-water sediment and surface water
- ~~Recreational and Subsistence Tribal Fisher – Direct exposure to beach sediment or in-water sediment, and fish consumption~~
- Fishers – Direct exposure to beach ~~sediment~~ or in-water sediment, consumption fish ~~consumption,~~ and shellfish ~~consumption~~
- Tribal Fishers – Direct exposure to beach and in-water sediment, consumption of fish
- Domestic Water User~~r~~ – D~~Hypothetical d~~irect exposure to ~~untreated~~ surface water used as a domestic water source

~~This draft document has been provided to EPA at EPA's request to facilitate EPA's comment process on the document in order for LWG to finalize the BHHRA. The comments or changes (including redlines) on this document may not reflect LWG positions or the final resolution of the EPA comments.~~

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- Infants - ~~Consumption of human milk~~Indirect exposure to bioaccumulative contaminants (PCBs, dioxin/furans, DDx, and PDBEs) in environmental media ~~was quantitatively assessed as a complete exposure pathway for all adult receptor populations exposed to bioaccumulative chemicals that were identified as COPCs for a given scenario~~via indirect exposures due to breastfeeding ~~(i.e., PCBs, dioxin/furans, and DDX)~~.

~~7.6~~7.1 SUMMARY OF RISKS

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~~Cancer risks and noncancer hazards were calculated for each of the exposure scenarios listed above for potential exposure to the contaminants selected as COPCs. The following sections present a summary of the risks for each of the media quantitatively evaluated in this BHHRA, and a discussion of the relative magnitude of the risk estimates for each media.~~

~~7.6.1 Summary by Exposure Scenario~~

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~~This section summarizes the risks for each of the media evaluated for potential risks in this BHHRA (beach sediment, in-water sediment, surface water, groundwater seep, fish tissue, and shellfish tissue). Table 5-196 presents a tabular summary of the risk estimates by exposure scenario. Figures 5-1 through 5-21 illustrate the contaminants contributing to risk for each exposure scenario by exposure point, and comparisons of risk across exposure points.~~

~~7.6.1.1 Fish Consumption~~

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~~Fish consumption risks were calculated for the adult and child non-tribal fish consumers, based on three different ingestion rates representing a range of potential consumption scenarios. Fish consumption risks were also evaluated for both single species- and multi-species diets (common carp, black crappie, brown bullhead, and smallmouth bass) based on consumption of either whole body or fillet with skin tissue. Fish consumption was assumed to occur at the same ingestion rate for 30 years for an adult and for 6 years for a child. It was assumed that all fish consumed were resident fish caught within the Study Area (from RM 2 to 11 for smallmouth bass, between RM 0 to 12 for carp, from RM 3 to 9 for brown bullhead and black crappie) or within a single exposure area (within a one mile area on both sides of the river for bass and within a 3 mile stretch of both sides of the river for crappie, carp and bullhead trout).~~

~~Fish consumption risks were also evaluated for adult and child tribal fishers based on an upper-bound ingestion rate for a multi-species diet consisting of resident fish species (common carp, black crappie, brown bullhead, and smallmouth bass) as well as sturgeon, lamprey, and salmon. Risks from the tribal fish diet were based on consumption of either whole body or fillet with skin tissue. Fish consumption was assumed to occur at the same ingestion rate for 70 years for an adult and for 6 years~~

~~for a child. . It was assumed that all fish consumed were caught within the Study Area.~~

~~Consumption of individual species by the non-tribal fisher resulted in cumulative cancer risks ranging from 3 x x 10^{-6} to 7 x x 10^{-2} for the scenarios including adult fisher, child fisher, combined adult and child fisher, or breastfeeding infant of an adult fisher consuming fish. . The cumulative HIs range from 0.5 to 5,000 for the child and adult non-tribal fish consumers. . The highest HI was 60,000 for the breastfeeding infant of a non-tribal fish consumer. . Risks from fish consumption by non-tribal fishers are primarily from exposure to PCBs.~~

~~Consumption of fish by the tribal fisher resulted in cumulative cancer risks ranging from 4 x x 10^{-4} to 2 x x 10^{-2} for the tribal adult consumer, tribal child consumer, and breastfeeding infant of tribal adult consumer. The highest HI was 400 for the tribal adult fisher, 800 for the tribal child consumer, and 9,000 for a breastfeeding infant of a tribal adult consuming fish. . Risks from fish consumption by tribal fishers are primarily from exposure to PCBs.~~

~~There were multiple uncertainties associated with the fish consumption scenarios of which the following were of primary significance: lack of site-specific fish consumption information, the small area assumed for exclusive collection of fish or shellfish consumed, fish consumption rates, tissue type and fish species consumed, cooking and preparation methods, and contributions from background. . Round 1 fillet tissue samples were not analyzed for PCB, dioxin, or furan congeners. . Therefore, the risks from consumption of black crappie and bullhead fillet tissue, which were only analyzed in Round 1, likely underestimate the actual risks. . However, a range of risks was calculated for fish consumption scenarios, which included samples that were analyzed for congeners, so the lack of analysis of contaminants in certain samples should not impact the conclusions of this BHHRA.~~

~~7.6.1.2 Shellfish Consumption~~

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~~Current and potential future shellfish consumption rates for the site are not known. . However, both crayfish and clams were evaluated for consumption risks. . Two different ingestion rates based on the nationwide survey for shellfish consumption for freshwater and estuarine habitats combined were used to calculate risks from shellfish consumption. . Shellfish consumption was assumed to occur at the same ingestion rate for 30 years. . It was assumed that all shellfish consumed were caught within the Study Area or within a single exposure area for spatial scales smaller than the Study Area. . Cumulative cancer risks from consumption of shellfish ranged from 9 x x 10^{-7} to 7 x x 10^{-4}. . The cumulative HIs range from 0.06 to 40 for shellfish consumption. . The highest HI was 800 for the breastfeeding infant of a shellfish consumer. .~~

~~In addition to the uncertainty of whether shellfish consumption actually occurs on an ongoing basis, there were other uncertainties associated with the shellfish~~

~~consumption scenarios of which the following were of primary significance: spatial scale of EPCs, shellfish consumption rates, shellfish species consumed, cooking and preparation methods, and contributions from background. .~~

~~7.6.1.3 Direct Exposure to In-Water Sediment~~

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~~Risks from in-water sediment exposure were estimated separately for each of the ½-mile river segment exposure areas on each side of the river, and for Study Area-wide exposure. . Each ½-river mile segment was considered a potential exposure area, regardless of the use of the area. . In-water sediment within the navigation channel was not included in the risk evaluation. . Risks from in-water sediment exposure were evaluated for exposures by in-water workers, tribal fishers, fishers, and divers. .~~

~~The cumulative cancer risks for all of the CT scenarios for direct exposure to in-water sediment were below 1 x x 10^{-4}, and only the tribal fisher CT scenario had cancer risks above 1 x x 10^{-6}. . For the RME scenarios, cumulative cancer risks were greater than 1 x x 10^{-6} but were below 1 x x 10^{-4}, with the exception of cancer risks above 1 x x 10^{-4} for in-water sediment by a tribal fisher at exposure areas RM 6W (risk is 2 x x 10^{-4} due primarily to PAHs) and RM 7W (risk is 3 x x 10^{-4} due primarily to dioxins). . The highest HI is 3.~~

~~There were multiple uncertainties associated with the direct exposure to in-water sediment scenarios of which the following were of primary significance: degree of sediment contact that occurs during fishing scenarios, spatial scale of in-water sediment EPCs, exposure parameters, bioavailability of contaminants in sediment, and contributions from background. . The uncertainties associated with exposure parameters and contributions from background were not quantified in this BHHRA. .~~

~~7.6.1.4 Direct Exposure to Beach Sediment~~

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~~Beaches were identified as potential human use areas associated with industrial upland sites (dockside workers), recreation (recreational users or fishers), and/or trespassing or transient use (transients). . Even if such beach use occurs, the extent to which the beach is used and the nature of the contact with sediments/beach is uncertain. . However, health protective assumptions were included in the risk analysis of this exposure pathway to provide an estimate of potential risks. .~~

~~The only CT scenarios for exposure to beach sediment resulting in risks above 1 x x 10^{-6} were the dockside worker (6 x x 10^{-6}) and tribal fisher and child recreational beach user scenarios (2 x x 10^{-6}). . The cumulative cancer risks for all of the CT scenarios were below 1 x x 10^{-4}. . The RME scenarios for exposure to beach sediment resulting in cumulative cancer risks above 1 x x 10^{-6} include: dockside worker, adult and child recreational beach user, tribal fisher and fisher. . The maximum cancer risk from RME scenarios was 9 x x 10^{-5} for the dockside worker exposure to beach sediment. None of the RME scenarios for exposure to beach sediment resulted in risks greater than 1 x x 10^{-4}. None of the scenarios resulted in~~

~~HIs exceeding 1. Risks above 1 x 10^-6 resulting from exposures to beach sediment are due primarily to arsenic, which is likely present at naturally occurring background concentrations, and benzo(a)pyrene.~~

~~There were multiple uncertainties associated with the direct exposure to beach sediment scenarios of which the following were of primary significance: spatial scale of beach sediment EPCs, exposure parameters, bioavailability of contaminants in sediment, and contributions from background. The uncertainties associated with exposure parameters and contributions from background were not quantified in the BHHRA.~~

~~7.6.1.5 Direct Exposure to Surface Water~~

~~Risks were evaluated for direct surface water exposures by transients, divers and adult and child recreational beach users. The scenarios resulting in cumulative cancer risks greater than 1 x 10^-6 were the diver in wet suit (1 x 10^-5) and the diver in dry suit (2 x 10^-6) at RM 6W due primarily to cPAHs. None of the direct surface water exposure scenarios resulted in HIs exceeding 1.~~

~~Surface water within the Study Area is not currently used as a domestic water source, nor are there plans to use surface water within the Study Area as a domestic water source in the future. However, risks were also evaluated for hypothetical exposure to untreated surface water used as a domestic water source by future residents. The maximum cumulative cancer risk for hypothetical exposure to untreated surface water was 9 x 10^-4, due primarily to cPAHs, and benzo(a)pyrene specifically. The child RME scenario for hypothetical exposure to surface water as a domestic water source was the only scenario with an exceedance of an HI of 1. The exceedance occurred at RM 8.5, primarily from exposure to MCPP (HQ for MCPP was 2).~~

~~7.6.1.6 Direct Exposure to Groundwater Seeps~~

~~Risks from exposures to groundwater seeps were evaluated for exposure by a transient for only one exposure point. The transient exposure scenario did not result in cumulative cancer risks greater than 1 x 10^-6 or HIs greater than 1.~~

~~7.6.2 Comparison of Risks Between Exposure Scenarios~~

A comparison of the estimated risk~~ ranges~~s ~~across~~ by exposure media can help focus risk management decisions by identifying the media contributing most to the overall human health risks ~~to human health~~ at the Study Area. As discussed in Sections 5, the magnitude of risk varies greatly across the different scenarios. Figures 7-1 and 7-2 display the ranges of total cumulative cancer risk and endpoint-specific HIs, respectively, for each media type, based on ~~mean~~ CT exposure assumptions for each media evaluated in the BHHRA. Figures 7-3 and 7-4 display the ranges of total cumulative cancer risk and cumulative HIs, respectively, based on RME assumptions. The estimated ~~As illustrated in Figures 7-1 and 7-2, the~~ risks ~~ranges for the scenarios~~

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~~assessing~~associated with consumption of fish and shellfish ~~tissue~~ are orders of magnitude higher than risks ~~for~~ from others scenarios, and exceed a cumulative cancer risk of 1 ~~x~~ x 10^{-4} and a HI of 1~~ ~~. ~~Figures 7-3 and 7-4 display the ranges of total cumulative cancer risk and cumulative HIs, respectively, based on RME assumptions, for each media type evaluated in the BHHRA. . As illustrated in Figures 7-3 and 7-4, the risk ranges for scenarios assessing consumption of fish and shellfish tissue are orders of magnitude higher than risks for other scenarios.~~ . S~~The only s~~cenarios ~~that exceed a~~for which the cumulative estimated cancer risk ~~of~~ is greater than 1 ~~x~~ x 10^{-4} or ~~a~~ the HI ~~of~~ is greater than 1 ~~are~~ are ~~the tissue consumption~~consumption of fish and shellfish scenarios and ~~and the scenario for~~ direct contact with in-water sediment by tribal and high frequency fishers.

~~7.6.3~~7.1.1 Contaminants Potentially Posing Unacceptable Risks

Contaminants were identified as potentially posing unacceptable risks if ~~they resulted in a~~the estimated cancer risk is greater than 1 ~~x~~ x 10^{-6} or ~~an~~ the HQ is greater than 1 ~~under~~ for any of the exposure scenarios ~~for any of the exposure point concentrations~~ evaluated in this BHHRA, regardless of the uncertainties associated with the estimates~~ ~~. Given the uncertainties in the analytical data discussed in Section 6, the preliminary COCs were assessed to select the final COCs for this BHHRA~~ ~~.

~~Four of the contaminants identified as potentially posing unacceptable risks~~ ~~α(alpha~~-, ~~β-beta~~, and ~~γgamma-hexachlorocyclohexane~~Hexachlorocyclohexane and heptachlor~~)~~ were ~~only~~ detected in fish tissue only as N-qualified data~~ ~~. Due to retention time issues in the analytical methods used for the Round 1 tissue samples, some of the pesticide tissue data were N-qualified, indicating that the identity of the chemical could not be confirmed~~ ~~. In the subsequent Rounds 2 and 3 sampling events, different analytical methods were used so that the identification of pesticides was not an issue in tissue ~~samples collected in Rounds 2 and 3.~~ . EPA guidance (1989) ~~does not~~ recommends ~~the~~ caution in the use of data where there are uncertainties in the identification of contaminants~~, as is the case in the N-qualified data.~~ . Therefore, if a chemical was identified as potentially posing unacceptable risks based only on the use of N-qualified data, that chemical is not recommended for further evaluation for potential risks to human health~~ ~~.

The contaminants potentially posing unacceptable risks to human health based on the results of this BHHRA that are recommended for further evaluation for potential risks to human health are presented in Table 7-1~~ ~~.

~~7.7~~7.2 PRIMARY CONTRIBUTORS TO RISK

~~In this BHHRA, there are certain exposure scenarios and contaminants that result in risks that are orders of magnitude higher than risks from other exposure scenarios and contaminants within the Study Area, and that exceed risk levels that generally warrant remedial action under CERCLA.~~ . One role of the BHHRA is

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to identify those contaminants that pose the greatest risks to current and future receptors, along with the media and exposures routes associated with those risks~~.~~ . This information is used to info~~rm RM~~ rm response actions~~. ~~. This section presents the primary contributors to human health risk at the Site~~. ~~. The exposure scenarios and chemicals discussed here represent a subset of the scenarios and contaminants evaluated in this BHHRA~~. ~~.

The focus on primary contributors to risk can assist with the development of the FS by focusing on those scenarios and contaminants associated with the greatest overall risk in the Study Area~~. ~~. While these scenarios and contaminants may be the focus of the remedial analyses, other exposure scenarios and contaminants potentially posing unacceptable risks may still be considered in remedial decisions for the Site.

Only those exposure scenarios and contaminants that resulted in an estimated cancer risk greater than 1~~x~~ x 10^{-6} or an HQ greater than 1 were considered in identifying the primary contributors to risk~~. ~~. Additional considerations in the selection of contributors included:

- The relative percentage of each contaminant's contribution to the total human health risk consistent with assumptions on exposure areas.
- Uncertainties associated with the exposure scenarios, such as the likelihood of future ~~risk scenarios~~site use, number of assumptions made in estimating exposure, or level of uncertainty in estimates of exposure variables.
- Frequency of detection, both on a localized basis and Study Area-wide.
- Comparison of risks within the Study Area to risks based on measured regional contaminant concentrations for similar exposure scenarios, indicating background or other anthropogenic sources of chemicals in the region.
- Magnitude of risk ~~exceedance above~~greater than EPA's target range for managing cancer risk of 1 x 10^{-4} to 1 x 10^{-6} and noncancer hazard of ~~one~~1.

The chemicals potentially posing unacceptable risks and the primary contributors to risk based on the above criteria ~~for the exposure scenarios evaluated in this BHHRA~~ are discussed below.

~~7.7.1~~7.2.1 Fish Consumption Scenarios

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Twenty six COCs (PCBs, dioxins, six metals, ~~Bis~~ Bis-2-ethylhexyl phthalate (BEHP), PAHs, hexachlorobenzene, and seven pesticides) ~~were~~ are identified as potentially posing unacceptable risks due to consumption of ~~for the~~ fish~~ consumption scenarios (i.e., both fisher and tribal fisher) based on exceedances of a cancer risk of 1 x x 10^-6 or HQ of 1~~:

- PCBs:~~ Total~~ Both total PCBs ~~resulted in cancer risk estimates exceeding 1 x x 10^-4 and/or HQs exceeding 1 for fish consumption. . Total~~and PCB TEQ ~~also resulted in cancer risk estimates exceeding 1 x x 10^-4 and/or HQs~~

~~exceeding 1 for fish consumption.~~ . ~~PCBs resulted in risk estimates that exceeded a cancer risk of 1 x~~ x ~~10~~$^{-4}$ ~~and/or HQ of 1 for both localized and Study Area-wide exposures. PCBs are considered a primary contributor to risk for the fish consumption pathway because~~based on ~~of~~ the magnitude of the estimated risks greater than 1 x 10^{-4}, ~~exceedances above the EPA target range for managing risk~~, the overall spatial scale ~~of the risk exceedances~~, and the relative contribution to cumulative risk estimates.

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- Dioxins/furans: ~~–~~ Total dioxin/furan TEQ ~~resulted in cancer risk estimates exceeding 1 x~~ x ~~10~~$^{-4}$ ~~and/or HQs exceeding 1 for fish consumption.~~ . ~~Total dioxin TEQ resulted in risk estimates that exceeded a cancer risk of 1 x~~ x ~~10~~$^{-4}$ ~~and/or HQ of 1 for~~ associated with both localized and Study Area-wide exposures~~. Dioxins are considered a primary contributor to risk for the fish consumption pathway because of~~ , the magnitude of the risk ~~exceedances~~estimates greater than 1 x 10^{-4}, the overall spatial scale ~~of the risk exceedances~~, and the relative contribution to cumulative risk estimates.

- Metals: ~~–~~ Antimony, arsenic, mercury, selenium, and zinc were associated with one or more fish consumption exposure scenarios that resulted in a risk estimate that exceeded a cancer risk of 1 ~~x~~ x 10^{-6} or HQ of 1.
    - The overall estimated risk estimates for ~~Arsenic~~ arsenic ~~resulted in cancer risk estimates that~~~~were~~are greater ~~exceeded~~ tha~~t~~n ~~a cancer risk of~~ 1 ~~x~~ x 10^{-4} ~~for~~ based on Study Area-wide exposures~~–~~.
    - The ~~Antimony exceeded an~~ HQ ~~of~~ associated with antimony ~~was~~is greater than 1 at ~~RM~~ RM 10 ~~for~~ based on consumption of whole body smallmouth bass tissue. ~~However, this result is only due to a single smallmouth bass sample with the~~ an ~~anomalously high result, as discussed in Section 6.1.14.~~ .
    - Lead, ~~was identified as a contaminant potentially posing unacceptable risk~~ based on a measured tissue concentration greater than the ~~exceedance of~~ protective tissue concentrations derived using blood lead models. ~~The risk exceedances for lead from fish consumption are~~However, this ~~was~~is due to only ~~due to only~~ a single ~~sample~~ result of smallmouth bass whole body tissue collected at ~~RM~~ RM 10 with ~~the~~ anomalously high result, as discussed in Section 6.1.14
    - Mercury, ~~resulted in risk estimates that~~~~was identified~~ based on an ~~exceeded a~~ HQ of 1 for both localized and Study Area-wide exposures.
    - Selenium, ~~exceeded~~ ~~was indentified~~ based on an HQ of 1 at ~~RM~~ RM 11 ~~only~~ for consumption of smallmouth bass fillet tissue, ~~due to~~in a single sample~~–~~. ~~Due to a limited number of detected concentrations of antimony and selenium (i.e., 5 detects out of 32 samples and 1 detect out of 23 samples, respectively), antimony and selenium also resulted in HQs greater than 1 Study Area-wide.~~

- Zinc~~-~~,~~slightly exceeded~~~~was identified~~ based on an HQ of ~~1 (HQ = 2)~~ ~~for fish consumption based on~~in a single sample of whole body common carp ~~tissue~~ collected from ~~RM~~ RM 4 to ~~RM~~ RM 8.~~–~~.

* BEHP~~: , was identified~~ , based on~~BEHP resulted in~~ cancer risk estimates greater than 1~~ x~~ x 10^{-6} ~~for consumption of whole body smallmouth bass and brown bullhead, based~~ on both a localized and Study Area-wide basis~~, for all ingestion rates,~~. ~~BEHP resulted~~ and ~~and~~ RME ~~in~~ cancer risk estimates greater than 1~~ x~~ x 10^{-4} and a HQ~~s~~ greater than 1 at ~~RM~~ RM 4 ~~for~~ based on consumption of smallmouth bass ~~at the 73 g/day and 142 g/day ingestion rates~~for recreational and subsistence fishers.

* PAHs:~~–~~ Benzo(a)anthracene, benzo(a)pyrene, dibenzo(a)anthracene, and total c~~arcinogenic~~ PAHs, ~~were identified as a contaminant potentially posing unacceptable risk for fish tissue consumption~~ based on cancer risk estimates ~~exceeding~~ greater than 1~~ x~~ x 10^{-6}. Cancer risk estimates for total carcinogenic PAH ~~exceeded~~ are greater than 1~~ x~~ x 10^{-6} at five river mile segments and Study Area-wide based on consumption of smallmouth bass and for two fishing zones and Study Area-wide based on consumption of common carp. ~~for all ingestion rates for consumption of smallmouth bass and only the 73 g/day and 142 g/day ingestion rates for consumption of common carp. No cancer risk estimates exceeded 1 x x 10^{-4}. For consumption of smallmouth bass, cancer risk estimates for total carcinogenic PAHs exceeded 1 x x 10^{-6} for five rive mile segments and Study Area-wide. For consumption of common carp, cancer risk estimates for total carcinogenic PAHs exceeded 1 x x 10^{-6} for two fishing zones and Study Area-wide. . PAHs account for less than 1% percent of the cumulative cancer risks where they were detected. .~~

* Organochlorine Pesticides:~~–~~ Aldrin, dieldrin, heptachlor epoxide, total chlordane, total DDD, total DDE, and total DDT ~~were~~are identified ~~were associated with one or more fish consumption exposure scenarios that resulted in a risk estimate that exceeded a~~based on estimated cancer risk~~s~~ ~~of~~greater than 1~~ x~~ x 10^{-6} or an HQ of 1. ~~These pesticides did not result in cancer risks greater than 1 x x 10^{-4}.~~
  - Aldrin, ~~was identified as a contaminant potentially posing unacceptable risk~~ based on cancer risk estimates ~~slightly~~ greater than ~~above~~ 1~~ x~~ x 10^{-6}~~, at only the 142 g/day ingestion rate for consumption of common carp~~ for subsistence fishers at ~~(~~localized areas and Study Area-wide~~)~~. ~~Aldrin only contributes approximately 0.01% percent to the total Study Area-wide risk for the whole body common carp diet.~~
  - Dieldrin, ~~was identified as a contaminant potentially posing unacceptable risk based on an exceedance of~~based on estimated cancer risks greater than 1~~ x~~ x 10^{-6} for consumption of all fish species ~~(smallmouth bass, common carp, black crappie, and brown bullhead),~~

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~~all ingestion rates, and~~ on a localized and Study Area-wide basis. ~~For the multi-species whole body tissue diet, dieldrin contributes to less than 1% percent of the site-wide risk from tissue consumption.~~

- Heptachlor epoxide, ~~was identified as a contaminant potentially posing unacceptable risk~~ based on estimated cancer risk estimates ~~slightly above~~greater than 1 ~~x~~ x 10^{-6}~~, at only the 142 g/day ingestion rate for consumption of common carp~~ for single-species diet of common carp by subsistence fishers ~~, and for~~at ~~one fishing zone (RM~~ RM 0 to ~~RM~~ RM 4~~)~~. ~~For this fishing zone, heptachlor epoxide contributes to 0.1% percent of cumulative risk from consuming whole body common carp.~~
- Total chlordane, ~~was identified as a contaminant potentially posing unacceptable risk based on an exceedance of~~based on estimated cancer risks greater than 1 ~~x~~ x 10^{-6} for consumption of all fish species ~~(smallmouth bass, common carp, black crappie, and brown bullhead), all ingestion rates, and~~ on a localized and Study Area-wide basis.
- DDD, ~~was identified as a contaminant potentially posing unacceptable risk~~ based on ~~an exceedance of~~estimated cancer risks greater than 1 ~~x~~ x 10^{-6} for consumption of all fish species ~~(smallmouth bass, common carp, black crappie, and brown bullhead), all ingestion rates, and~~ on a localized and Study Area-wide basis.
- DDE, ~~was identified~~ based on estimated cancer risks greater than 1 x 10^{-6} for consumption of all fish species on a localized and Study Area-wide basis, and ~~was identified as a contaminant potentially posing unacceptable risk based on an exceedance of 1 x~~ ~~x 1$0^{-6}$ for consumption of all fish species (smallmouth bass, common carp, black crappie, and brown bullhead), all ingestion rates, and on a localized and Study Area-wide basis. DDE also resulted in~~ an HQ ~~slightly~~ greater than 1 at ~~RM~~ RM 7, ~~for assuming~~based on consumption of smallmouth bass.
- DDT, ~~was identified as a contaminant potentially posing unacceptable risk~~ based on an ~~exceedance of~~estimated cancer risk greater than 1 ~~x~~ x 10^{-6} ~~for~~ based on consumption of all fish species ~~(smallmouth bass, common carp, black crappie, and brown bullhead), all ingestion rates, and~~ on a localized and Study Area-wide basis.
- PDBEs, based on an HQ greater than 1 for consumption of smallmouth bass and carp on a localized basis.

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Based on the magnitude ~~of risk,~~ and ~~the~~ relative contribution to the overall risk estimates ~~to risk~~, ~~and~~ as well as their frequency of detection, PCBs and dioxins/furans are considered the primary contributors to risk for fish consumption scenarios~~.~~. Estimated r~~The r~~isks ~~for~~ from PCBs and dioxins/furans ~~exceed a cancer risk of~~are greater than 1 ~~x~~ x 10^{-4} or an HQ of 1 for both the ~~mean~~ CT and ~~maximum~~ RME ~~exposure scenarios~~evaluations ~~for~~ at both localized and Study Area-wide exposures~~.~~. ~~Figure~~ Figure 7-~~-~~5 illustrates the relative contribution of individual contaminants to cumulative risk ~~percentages~~ estimates

~~of cancer risks for individual contaminants contributing to total cumulative risk for~~based on the Study Area-wide multi-species ~~-~~fish consumption ~~of fish tissue~~ by ~~an~~ adult subsistence fisher~~rs~~r~~, based on Study Area-wide EPCs for a multi-species diet. .~~. ~~Separate charts are shown for diets based on whole body fish consumption and fillet tissue consumption. . As illustrated in the pie charts in Figure 7-5,~~ PCBs are the primary contributor to the overall risk estimate, and taken together with ~~for fish consumption and~~ dioxins/furans expressed as a TEQ ~~are a secondary risk contributor for fish consumption of both whole body and fillet tissue diets~~account for the majority of the estimated risk~~. .~~. ~~A similar pattern is shown in Figure 7-6, which illustrates the relative percentage of cancer risk for consumption of fish tissue by an adult tribal fisher, based on Study Area-wide EPCs for a multi-species diet for both whole body and fillet tissue consumption. . For both the fisher and tribal fisher, and for both whole body and fillet tissue diets,~~Figure 7-6 shows the relative contributions to the overall risk estimate based on Tribal fish consumption. ~~PCBs contribute over 90% percent of the overall cancer risk and result in an HQ that is up to 57 times higher than any other HQ from whole body tissue consumption, and up to 153 times higher than any other HQ from fillet tissue consumption by adults. .~~

PCBs and dioxins/furans have been detected in fish tissue collected outside of the Study Area in both the Willamette and Columbia Rivers. In a risk assessment for the mid-Willamette (EVS 2000), PCB concentrations were found to result in a HQ greater than 1 assuming both a 142 g/day and a 17.5 g/day consumption rate, and an estimated cancer risk greater than 1 x 10^{-4} for the 142 g/day consumption rate. Dioxins and furans were also found to result in an estimated cancer risk greater than 1 x 10^{-4} using a 142 g/day consumption rate (non-cancer endpoints were not evaluated for dioxins and furans). In the Columbia River Basin Fish Contaminant Survey (EPA 2002c), the estimated cancer risks associated with PCBs and dioxins/furans were greater than 1 x 10^{-4} assuming a consumption rate of 142 g/day, and the estimated risk due to PCBs was greater than 1 x 10^{-4} assuming a consumption rate of 7.5 g/day. While ambient concentrations have not been established for fish tissue, as discussed in Section 6.4.2, regional tissue concentrations may be associated with unacceptable risks from fish consumption, especially at higher consumption rates. ~~The contributions of background concentrations to these risk estimates may exceed the risk levels that generally warrant remedial action under CERCLA. . While background concentrations have not been established for fish tissue, as discussed in Section 6.4.2, regional tissue concentrations may be associated with unacceptable risks from fish consumption, especially at higher ingestion rates. On a regional level, PCBs and dioxins/furans have been detected in fish tissue collected in the Willamette and Columbia Rivers, outside of the Study Area. . In a risk assessment for the mid-Willamette (EVS 2000), PCBs were found to result in an HQ greater than 1 for both the 142 g/day and 17.5 g/day ingestion rates, and a cancer risk greater than 1 x x 10^{-4} for the 142 g/day ingestion rate. . Dioxins and furans were also found to result in a cancer risk greater than 1 x x 10^{-4} for the 142 g/day ingestion rate~~

~~(non-cancer endpoints were not evaluated for dioxins and furans). . In the Columbia River Basin Fish Contaminant Survey (EPA 2002c), PCBs were found to result in cancer risks greater than 1 x x 10^{-4} and HQs greater than 1 for the 142 g/day and 7.5 g/day[9] ingestion rates for the general public consumption of resident fish. . Dioxins and furans were also found to result in a cancer risk greater than 1 x x 10^{-4} for the 142 g/day ingestion rate (non-cancer endpoints were not evaluated for dioxins and furans).~~ While the concentrations in the Study Area are higher than the regional tissue concentrations, the sources of PCBs and dioxins and furans in regional tissue data are unknown, and efforts are underway to reduce regional tissue concentrations~~, the regional tissue data indicate that CERCLA actions alone may not be adequate to achieve a target risk level of 1 x x 10^{-6} for based on some of the assumptions evaluated in this BHHRA~~.

~~9.0~~

~~7.7.2~~7.2.2 Shellfish Consumption Scenarios

Seventeen contaminants (PCBs, dioxins, arsenic, PAHs, pentachlorophenol, and five pesticides) were identified as potentially posing unacceptable risks ~~for~~ due to consumption of shellfish ~~consumption~~, based on ~~exceedances of the cumulative~~estimated cancer risks ~~of~~ greater than 1 ~~x~~ x 10^{-6} or a HQ of 1~~,~~: ~~including PCBs, dioxins, arsenic, PAHs, pentachlorophenol, and five pesticides:~~

- PCBs: ~~–~~ Total PCBs and PCB TEQs, ~~were identified resulted in~~based on cancer risk estimates ~~exceeding~~ greater than 1 ~~x~~ x 10^{-4} and/or HQs ~~exceeding~~ greater than 1 for shellfish consumption~~. . Total PCB TEQ also resulted in cancer risk estimates exceeding 1 x x 10^{-4} and/or HQs exceeding 1 for shellfish consumption. . PCBs resulted in risk estimates that exceeded a cancer risk of 1 x x 10^{-4} and/or HQ of 1 for~~in ~~both~~ localized and Study Area-wide exposures. PCBs are considered a primary contributor to risk for the shellfish consumption pathway because of the magnitude ~~of the risk exceedances,~~ and spatial scale of the risk estimates greater than 1 x 10^{-4} ~~of the risk exceedances~~, their ~~the~~ relative contribution to cumulative risk estimates, and the frequency of detection.

- Dioxins/furans: ~~–~~ Total dioxin/furan TEQs~~, resulted in were identified~~ based on cancer risk estimates ~~exceeding~~ greater than 1 ~~x~~ x 10^{-4} and/or HQs ~~exceeding~~ greater than 1 for shellfish consumption~~. . Dioxins and furans resulted in risk estimates that exceeded a cancer risk of 1 x x 10^{-4} and/or HQ of 1 for~~ in ~~both~~ localized and Study Area-wide exposures. Dioxins are considered a primary contributor to risk for the shellfish consumption pathway because of the magnitude and spatial scale of the risk estimates greater than

[9] ~~The low ingestion rate used in the Columbia River Basin Fish Contaminant Survey is lower~~ less ~~than the lowest ingestion~~ consumption ~~rate used in this BHHRA, which was 17.5 g/day.~~

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1 x 10^{-4}, their relative contribution to cumulative risk estimates, and the frequency of detection~~magnitude of the risk exceedances, spatial scale of the risk exceedances, the relative contribution to cumulative risk, and the frequency of detection~~.

- Arsenic: ~~Arsenic was identified~~B ~~as a contaminant potentially posing unacceptable risk b~~ased on cancer risk estimates that ~~exceeded~~ greater than 1 ~~x~~ x 10^{-6} ~~for~~ from ~~both~~ clams and crayfish ~~,~~ at both ~~ingestion~~ consumption rates~~,~~ and on a localized and Study Area-wide scale. No cancer risk estimates exceeded 1 ~~x~~ x 10^{-4}~~.~~. Though arsenic ~~was~~ is identified as a contaminant potentially posing unacceptable risk on both a localized and Study Area-wide spatial scale, ~~the~~ concentrations in shellfish tissue ~~may~~ are likely ~~be~~ due in part to the contribution of ~~naturally occurring~~ background concentrations.

- cPAHs: B~~cPAHs were identified as a contaminant potentially posing unacceptable risk b~~ased on cancer risk estimates ~~that exceeded~~greater than 1 ~~x~~ x 10^{-6} ~~for~~ from both clams and crayfish~~,~~ at both ingestion rates~~,~~ and on a localized and Study Area-wide scale. Cancer risk estimates greater than 1 x 10^{-4} ~~for total cPAHs across all exposure areas and exposure scenarios ranged from 2 x x 10^-8 to 5 x x 10^-4, and exceeded 1 x x 10^-4 for the~~from clams collected at locations ~~RM~~ RM 5W and ~~RM~~ RM 6W and assuming a consumption rate of 18 g/day ~~ingestion rate for clams collected at locations RM 5W and RM 6W.~~ . cPAHs are considered a primary contributor to risk for the shellfish consumption pathway at those locations because of the magnitude of the risk ~~exceedances~~ estimates and their relative contribution to the cumulative risk.

- Pentachlorophenol:~~–~~ Pentachlorophenol was detected only ~~detected~~ in a single crayfish composite sample collected near ~~RM~~ RM 8~~—~~. It was not detected in the remaining ~~one out of 41~~ 40 shellfish samples~~, which was a crayfish composite sample collected near RM 8~~. This ~~one~~ single detection of pentachlorophenol resulted in a cancer risk estimate within the range of 1 ~~x~~ x 10^{-6} to 1 ~~x~~ x 10^{-4}~~—~~.

- Organochlorine p~~P~~esticides: Aldrin, dieldrin, total DDD, total DDE, and total DDT, ~~were associated identified~~ based ~~with one or more shellfish consumption exposure scenarios that resulted in a risk estimate that exceeded~~on an estimated ~~a~~ cancer risk ~~of~~ greater than 1 ~~x~~ x 10^{-6} or a HQ of 1~~.~~ . ~~These pesticides were not associated with shellfish consumption scenarios that resulted in a cancer risk estimate above 1 x x 10^-4.~~
    - Aldrin, ~~was identified as a contaminant potentially posing unacceptable risk~~ based on an estimated cancer risk ~~estimates above~~greater than 1 ~~x~~ x 10^{-6} for ~~ingestion~~ consumption of clams at ~~RM~~ RM 8W and on a Study Area-wide basis, ~~tissue, for the~~assuming a

consumption rate of 18 g/day~~ ingestion rate only, and for one location (near RM 8W) and Study Area-wide. ~~.

- Dieldrin, ~~was identified as a contaminant potentially posing unacceptable risk~~ based on an estimated cancer risk ~~estimates above~~greater than 1 ~~x~~ x 10^{-6} for ~~ingestion~~ consumption of clams near ~~RM~~ RM 8W and Study Area-wide, assuming a consumption rate of ~~tissue, for the~~ 18 g/day ~~ ingestion rate only, and for one location (near RM 8W) and Study Area-wide~~.
- Total DDD, ~~was identified~~ based on an estimated cancer risk greater than 1 x 10^{-6} for consumption of clams near ~~RM~~ RM 8W and Study Area-wide, assuming a consumption rate of 18 g/day~~was identified as a contaminant potentially posing unacceptable risk based on cancer risk estimates above 1 x~~ x ~~10^{-6} for ingestion of clam tissue, for the 18 g/day ingestion rate only, and for one location (near RM 6W) and Study Area-wide~~.
- Total DDE, ~~was identified~~ based on an estimated cancer risk greater than 1 x 10^{-6} for consumption of clams near ~~RM~~ RM 6W, ~~RM~~ RM 7W, ~~RM~~ RM 8W and Study Area-wide, assuming a consumption rate of 18 g/day~~was identified as a contaminant potentially posing unacceptable risk based on cancer risk estimates above 1 x~~ x ~~10^{-6} for ingestion of clam tissue, for the 18 g/day ingestion rate only, and for three locations (near RM 6W, RM 7W, and RM 8W)~~.
- Total DDT, ~~was identified~~ based on an estimated cancer risk greater than 1 x 10^{-6} for consumption of clams near ~~RM~~ RM 6W and ~~RM~~ RM 7W, assuming a consumption rate of 18 g/day~~was identified as a contaminant potentially posing unacceptable risk based on cancer risk estimates above 1 x~~ x ~~10^{-6} for ingestion of clam tissue, for the 18 g/day ingestion rate only, and for only two locations (near RM 6W and RM 7W)~~.

Based on the magnitude ~~of risk, the~~and relative contribution to the total risk estimates, and the frequency of detection, PCBs, dioxins/furans, and cPAHs are considered the primary contributors to risk for shellfish consumption. PCBs and dioxins/furans contribute approximately 58~~%~~ percent and 91 percent, respectively, of the cumulative cancer risk ~~for~~ from consumption of clams ~~consumption~~ and ~~approximately 91% percent for~~ crayfish ~~consumption for the Study Area. ~~. ~~Total~~ cPAHs contribute approximately 35~~%~~ percent and 5 percent, respectively, of the cumulative cancer risk ~~for~~ from consumption of clams ~~consumption (for~~(undepurated samples)~~)~~ and ~~approximately 5% percent for~~ crayfish ~~consumption for the Study Area. ~~. PCBs and dioxins/furans are considered primary contributors to risk on a Study Area-wide basis~~. ~~, and cPAHs are considered primary contributors to risk on a localized basis (~~RM~~ RM 5W and ~~RM~~ RM 6W)~~. ~~. ~~PCBs are the primary contributors to risk and dioxins/furans are the secondary contributors to risk for shellfish consumption.~~

~~7.7.3~~7.2.3 In-Water Sediment Scenarios

PAHs (primarily benzo[a]pyrene), arsenic, PCBs, and dioxins ~~The contaminants~~ are identified as contaminants potentially posing unacceptable risk ~~identified~~ for in-water sediment ~~are PAHs (primarily benzo[a]pyrene), arsenic, PCBs, and dioxins~~. PAHs and dioxins ~~were~~ are identified ~~as contaminants potentially posing unacceptable risk~~ for all of the in-water sediment scenarios, ~~and~~ arsenic and PCBs were identified ~~as contaminants potentially posing unacceptable risk~~ for the tribal fisher and high frequency fisher scenarios only~~.~~. The relative contribution of each contaminant to cumulative cancer risk estimates ~~of the contaminants to the cumulative cancer risks~~ varied by river mile~~.~~. ~~Risks from cPAHs across all exposure areas and exposure scenarios ranged from 1 x x 10^{-10} to 2 x x 10^{-4}.~~ ~~For the entire~~Throughout the Study Area, estimated risks from ~~total~~ cPAHs and dioxins/furans ~~through direct contact with sediment~~ each contributed approximately 50~~%~~ percent of the cumulative cancer risk estimate~~.~~. As previously discussed, cumulative cancer risks associated with arsenic may be due in part to naturally occurring concentrations in ~~background~~ sediment ~~concentrations.~~. Cumulative cancer risks from PCBs ~~above~~ is greater than 1 ~~x~~ x 10^{-6} ~~for PCBs are associated with only~~at four ~~½~~ one-half mile river segments, and ~~for~~ from dioxins ~~are associated with only~~at two ~~½~~ one-half mile ~~river~~ segments. Cumulative cancer risks from cPAHs ~~above~~ are greater than 1 ~~x~~ x 10^{-6} for ~~PAHs are associated with~~at ~~twenty-two~~22 ~~½~~ one-half mile river segments. Carcinogenic PAHs are considered the primary contributors to risk ~~contaminant~~ for in-water sediment on a Study Area-wide basis due to the relative magnitude ~~of the cumulative risk and the number~~ and spatial scale of ~~the risk exceedances~~estimated risks greater than 1 x10^{-4}~~.~~. PCBs and dioxins are considered primary contributors to risk on a localized basis ~~(~~at ~~RM RM~~ RM 8.5W ~~[~~for PCBs~~]~~ and ~~RM RM~~ RM 7W for ~~[~~dioxins/furans~~])~~.

~~7.7.4~~7.2.4 Beach Sediment Scenarios

PAHs (primarily benzo[a]pyrene) and arsenic ~~The contaminants~~were identified as potentially posing unacceptable risk ~~identified for~~in beach sediment ~~are PAHs (primarily benzo[a]pyrene) and arsenic~~. Risks ~~above~~ greater than 1 ~~x~~ x 10^{-6} ~~resulting from~~associated with exposure to arsenic in beach sediment are likely due in part to naturally occurring ~~background~~ concentrations of arsenic. ~~If the contribution of naturally occurring background concentrations of arsenic is subtracted from the cumulative risk, then the primary contributor to risk for beach sediment is benzo(a)pyrene.~~ Risks ~~above~~ greater than 1 ~~x~~ x 10^{-6} ~~resulting~~ associated with ~~from~~ exposure to benzo(a)pyrene was limited to a few locations, with the maximum cumulative cancer risk ~~associated with~~at beach location 06B025. ~~Therefore, direct exposure to beach sediment containing benzo(a)pyrene at beach 06B025 is considered a primary contributor to risk for beach sediment.~~ .

~~7.7.5~~7.2.5 Surface Water Scenarios

PAHs ~~The~~ are the primary contributor to risks ~~for~~ associated with direct contact ~~with~~ to surface water. Estimated cancer risks are greater than 1 x 10^{-4} assuming use of river

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water as a domestic water source, and greater than 1 x 10^{-6} for divers at ~~RM~~ RM 6W. However, as noted in Section 5.2.8, the estimated risks associated with dermal exposure to PAHs in water should be used with caution, as PAHs are not within the Effective Prediction Domain of the model used to estimate the dermally-absorbed dose~~. –~~. ~~is exposure to PAHs in surface water by divers at RM 6.0 W, because this is the only scenario and location with risk exceedance of 1 x~~ x 10^{-6} ~~or HI greater than 1. However,~~Additional risk management considerations during remedy selection should consider the limited spatial scale and ~~high~~ degree of uncertainty associated with the diver exposure assumptions.

~~Risks were also evaluated for hypothetical exposure to untreated surface water used as a domestic water source by future residents.~~ ~~Cumulative cancer risks were up to 3 x~~ x ~~10^{-4} for adults, and up to 7 x~~ x ~~10^{-4} for child residents primarily due to benzo(a)pyrene.~~ ~~The only~~ HIs ~~that were~~ greater than 1 at Multnomah Channel and ~~RM~~ RM 8.5 ~~were~~ were associated with use of river water as a drinking water source~~for a child resident under the RME scenario at Multnomah Channel and RM 8.5, due primarily to ingestion of MCPP in surface water. –~~. ~~Because this is a hypothetical scenario, it is not considered a primary contributor to risk for the Study Area.~~

~~7.7.6~~7.2.6 Summary of Primary Contributors to Risk

~~As per EPA guidance for the role of risk assessment in remedy selection under CERCLA (EPA 1991a), EPA uses the general risk range of 1 x~~ x ~~10^{-6} to 1 x~~ x ~~10^{-4} as a "target range" within which the EPA manages risk during the remedy selection. Furthermore, if the cumulative cancer risk to an individual based on RME assumptions is less than 1 x~~ x ~~10^{-4} and the non-cancer HQ is less than 1, remedial action generally is not warranted at a site (EPA 1991a).~~ ~~DEQ guidance sets an acceptable risk level of 1 x~~ x ~~10^{-6} for individual chemicals and 1 x~~ x ~~10^{-5} for cumulative risks (OAR 340-122-0115).~~ ~~While chemicals potentially posing unacceptable risks were identified based on exceeding a cancer risk of 1 x~~ x ~~10^{-6} or HQ of 1, the only exposure scenarios with cancer risks exceeding 1 x~~ x ~~10^{-4} or HQ greater than 1 are fish consumption and shellfish consumption and direct exposure to in-water sediment for two ½ river mile segments.~~

~~The primary exposure scenario contributing to risk for the Study Area is fish consumption, and the contaminants contributing to that risk are PCBs and dioxins/furans.~~ ~~PCBs and dioxins/furans both resulted in cancer risks greater than 1 x~~ x ~~10^{-4} and HQs greater than 1 for fish consumption for both localized and Study Area-wide exposures.~~ ~~PCBs and dioxins/furans contribute approximately 98%~~ ~~percent of the cumulative cancer risk for fish consumption.~~ ~~Regionally, fish consumption also results in risk estimates exceeding cumulative risks of 1 x~~ x ~~10^{-4} or HQ of 1 based on data collected from the Willamette and Columbia Rivers outside of the Study Area (EVS 2000, EPA 2002c).~~ ~~In those studies, both PCBs and dioxins/furans resulted in cancer risks greater than 1 x~~ x ~~10^{-4} and/or HQs greater than 1 for fish consumption.~~ ~~The concentrations of PCBs in~~

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~~regional tissue are lower than in the Study Area, and the sources of PCBs in regional tissue are unknown.~~ . ~~The secondary exposure scenario contributing to risk is consumption of shellfish; however, it is not known to what extent shellfish consumption actually occurs on an ongoing basis within the Study Area.~~ .

The identification of the primary contributors to human health risks can help provide focus to the FS by identifying a smaller number of chemicals and exposure scenarios that have the largest contribution to overall risk~~.~~. To provide context for the significance of the remedial actions to the protection of human health, the uncertainties associated with the exposure assumptions and potential contribution of background sources of contaminants to the Study Area should be considered when evaluating primary contributors to human health risks ~~during~~ in the FS.

~~9.0 CONCLUSIONS~~

~~A summary of chemicals contributing to risk by exposure scenario is provided in Table 7-1, and risk ranges by exposure scenario are presented in Table 5-203. The following presents the major findings of this BHHRA:~~

~~SUMMARY OF RISK CHARACTERIZATION~~

~~Cancer risk and noncancer hazard from site-related contamination was characterized based on current and potential future uses at Portland Harbor, and a large number of different exposures scenarios were evaluated. Exposure to bioaccumulative contaminants (PCBs, dioxins/furans, and organochlorine pesticides, primarily DDE/DDD/DDT) via consumption of resident fish consistently poses the greatest potential for human exposure to in-water contamination. In general, the risks associated with consumption of resident fish are greater by an order of magnitude or more than risks associated with exposure to sediment or surface water. The greatest non-cancer hazard estimates are associated with bioaccumulation through the food chain and exposure to infants via breastfeeding. Because the smallest scale over which fish consumption was evaluated was per river mile, the resolution of cumulative risks on a smaller scale is not informative. The highest relative cumulative risk or hazard estimates are at RM 2, RM 4, RM 7, Swan Island Lagoon, and RM 11. However, assuming exposure to sediment alone, areas posing the greatest risk are RM 6W, RM 7W, RM 8.5W, and RM 11E, shellfish consumption alone poses the greatest risks at RM 4E, RM 5W, RM 6W, and RM 6E.~~

- ~~Fish consumption is the exposure scenario that is considered the primary contributor to risk for this site. Risks resulting from the consumption of fish are generally orders of magnitude higher than risks resulting from direct contact with sediment, surface water, or groundwater seeps. Risks from fish consumption are within or above the cumulative cancer risk range of 1 x~~ 10^{-6} ~~to 1 x~~ 10^{-4} ~~and exceed an HI of 1 for most exposure scenarios evaluated, including both RME and CT assumptions. Risk estimates for shellfish consumption scenarios were also within or above the cumulative cancer risk range of 1 x~~ 10^{-6} ~~to 1 x~~ 10^{-4} ~~and exceeded an HI of 1 for most exposure scenarios evaluated, including both RME and CT assumptions. The evaluation of shellfish consumption was completed at the direction of EPA. With the exception of two ½-mile river segments for the tribal fisher scenario and one location for the hypothetical use of untreated surface water as a drinking water source by a future resident, all of the direct contact scenarios result in risks within or below the EPA target cancer risk range of 1 x~~ 10^{-6} ~~to 1 x~~ 10^{-4}~~. The direct contact scenarios also result in non-cancer hazards below the target HI of 1, with the exception of one ½-river mile segment for in-water sediment and one location for hypothetical use of untreated surface water as a drinking water source.~~

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- ~~For fish consumption, which is the pathway with the highest risk estimates, PCBs are the primary contributor to risk, and dioxins/furans are the secondary contributor to risk.~~ .

- ~~The uncertainties associated with the tissue consumption scenarios should be considered during the FS.~~ . ~~The fish tissue consumption risks in this BHHRA incorporate assumptions that may under- or more likely over-estimate the actual risks.~~ .

- ~~The contribution of background sources is an important consideration in risk management decisions.~~ . ~~For example, arsenic concentrations in beach sediment contribute approximately 50%~~ percent ~~of cumulative risk from exposure from this medium for the highest-risk scenarios, yet arsenic concentrations detected in beach sediment within the Study Area are comparable to Oregon DEQ-established background levels.~~

~~The results of the BHHRA will be used to produce~~ derive ~~risk-based PRGs and AOPCs for the FS, as well as to develop risk management recommendations for the Site.~~ . ~~In addition, the BHHRA may be consulted by risk managers as they deliberate practical risk management objectives during the course of the FS.~~

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